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TITLE : **S**tudy of **P**olicies regarding **E**conomic instruments **C**omplementing **T**ransport **R**egulation and the **U**ndertaking of physical **M**easures

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APPENDICES

EXECUTIVE SUMMARY

The SPECTRUM project aims "to develop a theoretically sound framework for defining combinations of economic instruments, regulatory and physical measures in reaching the broad aims set by transport and other relevant policies". Within this main objective, the goal is to assess the extent to which it is possible to substitute economic transport instruments with physical and regulatory instruments and to investigate evidence of synergy and complementarity between the instruments.

The aim of the work on 'Measurement and Treatment of High Level Impacts' presented in this deliverable is to provide practical guidance on measurement and treatment of impacts on both passengers and freight transport due to different policy instruments and instrument packages, and especially for the SPECTRUM case studies. It follows the SPECTRUM assessment framework that has been defined in Deliverable 5 of the SPECTRUM project (SPECTRUM, 2003) and takes account of the theoretical analysis as well as guidelines for elements to be taken into account in the objective function that Deliverable 4 (SPECTRUM, 2003) specifies.

This deliverable takes its structure from the high level framework for the evaluation of transport instrument and instrument packages presented in Deliverable 5 comprising impacts on all actors in the transport system. At first the framework is fine-tuned to encompass more specific impacts and their indicators to meet the objectives and sub-objectives of a sustainable and effective transportation system for both passengers and freight and in all contexts, urban, inter-urban as well as rural. Secondly, the evaluation of impacts due to transport policy measures is discussed taking account of all actors in the transport sector, government and other authorities, producers and the users.

The SPECTRUM assessment framework is by its economic approach based on welfare economics. According to this approach impacts that can be monetised will be included in a Cost Benefit Analysis (CBA). Impacts that cannot be assigned a monetary value can be dealt with using a Multi Criteria Analysis (MCA) or descriptive assessment methods. Some impacts have both a monetised part and a non-monetised part and thus need to be included in both assessment frameworks. It should be noted, though, that whilst the focus is on the monetary assessment methods we will not overlook other dimensions of appraisal.

Guidance on the measurement and treatment of transport impacts has been divided into six sectors each of which have been treated separately, namely impacts on passengers and freight (excluding externalities and equity issues), impacts on the transportation system as a whole, measurement and treatment of safety and accident impacts, measurement and treatment of other externalities and finally measurement and treatment of equity aspects. The practical guidance for the measurement and treatment of the impacts in the assessment procedure follow state-of-the-art principles and procedures comprising generally three facets: at first, where relevant some background theory is presented, secondly general advice mainly addressed to professionals is given, and finally especially the SPECTRUM case studies are addressed and given specific guidance.

Although the guidance put forward in this deliverable will be tested in the SPECTRUM case studies it should be noticed that in a practical context it may not be possible to include all objectives and sub-objectives and it will be necessary to make simplifications in order to get reliable results. Following the specific recommendations for the case studies both general and case study specific comments on the relevance and potential of addressing the vast set of possible impacts are presented. It is presumed that whilst some impacts are commonly well considered in all studies (such as e.g. most components of the generalised cost, consumer's and producer's surplus and accidents), some can be included in lesser detail (externalities like air pollution, global warming and noise) and some are presently very difficult or even impossible to address in most of the case studies (visual intrusion, fragmentation, most impacts on equity and impact on economic growth).

1 Introduction

The aim of this deliverable 'Measurement and Treatment of High Level Impacts' is to provide practical guidance on measurement and treatment of impacts on both passengers and freight transport due to different policy instruments and instrument packages in general, and especially for the SPECTRUM case studies. It follows the SPECTRUM assessment framework that has been defined in Deliverable 5 (SPECTRUM, 2003) including

- relevant policy objectives for both passenger and freight transport;
- definition and classification of instruments;
- definition of framework for scale of level of accuracy for both urban and inter-urban case studies and
- description of assessment methods;

and takes account of the theoretical analysis as well as guidelines for elements to be taken into account in the objective function that Deliverable 4 (SPECTRUM, 2003) presents.

This deliverable takes its structure from the high level framework for the evaluation of transport instrument packages presented in Deliverable 5 comprising impacts on all actors in the transport system as well as effects on other bodies. In addition to the direct impacts of transport policies there are a great number of second and even third order impacts that make the system very complex to manage. Therefore the main stress in the work will be on current stable direct impacts and well-known second order impacts.

The SPECTRUM assessment framework is by its economic approach based on welfare economics and comprises both the economic efficiency part and the equity part. According to this approach impacts that can be monetised will be included in a Cost Benefit Analysis (CBA). Impacts that cannot be assigned a monetary value can be dealt with using a Multi Criteria Analysis (MCA) or descriptive analysis methods. Some impacts have both a monetised part and a non-monetised part and thus need to be included in both parts of the assessment framework. As an example, most impacts on environment and health can be monetised but for some impacts no common consensus of their valuation yet exists.

Guidance on the measurement and treatment of transport impacts has been divided into six sectors each of which have been treated separately, namely impacts on passengers and freight (excluding externalities and equity issues), impacts on the transportation system as a whole, measurement and treatment of safety and accident impacts, measurement and treatment of other externalities and finally measurement and treatment of equity aspects. The practical guidance for the measurement and treatment of the impacts in the assessment procedure follow state-of-the-art principles and procedures comprising generally three facets: at first, where relevant some background theory is presented, secondly general advice mainly addressed to professionals is given, and finally especially the SPECTRUM case studies are addressed and given specific guidance. Although the guidance put forward in this deliverable will be tested in the SPECTRUM case studies it should be noticed that in a practical context it may not be possible to include all objectives and sub-objectives and it will be necessary to make simplifications in order to get reliable results.

At first, in Chapter 2 the high level evaluation framework will be shortly introduced with more details to refresh the relations between the SPECTRUM objectives, impacts and indicators that will be studied in the case studies. It also summarises the appraisal methods and gives the common format of appraisal outputs. Finally, the transport impacts on economic growth and how it should be measured is discussed. However, in the case studies where the impacts of a specific project, the substitution and complementarity of instruments, are studied, the impacts on economic growth are not in the scope of work.

Chapter 3 discusses assessment of impacts on economic efficiency i.e. net user benefits for consumers derived from passenger transport since external impacts (incl. accident risk, pollution, noise and congestion) and equity are discussed in chapters of their own. At first, impacts on transport demand and how these should be included in the assessment analysis are discussed. Following this, the assessment framework for passengers is presented together with the elements of the generalised cost for a passenger that are affected by transport policy actions. The values of time of a journey are the most debated subject and thus play a major role of this chapter. Time savings usually play a key role for the economic viability of a transport policy intervention. Finally, recommendations for both urban and inter-urban passenger transport are given including values to use, thereby covering both sets of case studies in SPECTRUM.

In Chapter 4 the measurement of impacts on freight transport is analysed, classified both by different branches of industry and by spatial dimension. The benefits of freight transport improvements may be large. An understanding of the broad market forms and behavioural responses to policies in these are established and a framework is provided to analyse the effects of policy measures on freight transport. Four different methods to be used in the case studies are presented including a general model to determine crucial elements in the assessment of the impacts on freight transport, description of the relation between demand for freight transport and economic activity and a partial equilibrium model forming a framework for the demand for and supply of freight transport by mode. Indirect effects in and outside the freight sector are discussed as well. Finally the most important conclusions are reported and recommendations are given for the case studies.

Assessment of the transport system performance is discussed in Chapter 5. It covers those transport system objectives of SPECTRUM that are not included in the previous chapters of passengers and freight. The transport system is here assessed from the point of view of the government, infrastructure provider, financier and operator. First, some fundamental concepts of transport system performance are revealed and some technical matters of evaluation are discussed. Then, we look deeper to the items that should be covered in the case studies. Finally, some practical recommendations on how all this can be carried out using typical state-of-the-art transport models are given.

The aim of Chapter 6 is to present a methodology for the calculation of accident costs. Both total accident costs and marginal accident costs are discussed and their difference explained. Moreover, a distinction is made between external and internal accident costs. Based on the literature and theoretical models derived for calculation of the total and marginal external accident cost the different components of the accident costs are derived. Then, it is explored how each of these components can be calculated. The chapter concludes with an example and some recommendations.

In Chapter 7 effects of policies in terms of externalities they generate are studied. This chapter looks at noise, congestion, air pollution and visual intrusion as accidents have already been discussed in the previous chapter. In addition, values or more precisely a range of values for these externalities based on previous research are suggested. Externality research has concentrated primarily on a limited set of external costs, i.e. those associated to the emission of air polluting substances, to accidents, to global warming and, concerning transport, to congestion. Noise pollution has been extensively investigated, but the current body of knowledge is still insufficient, while other externalities are altogether largely under-documented, such as e.g. visual intrusion, community severance, water and soil pollution, and odours.

The two broad classes of objectives in SPECTRUM are economic efficiency and equity. Efficiency-enhancing measures like marginal cost pricing and optimal investment have important distributional impacts. Thus the trade-off between economic efficiency and equity is central to decision-making. Whether the introduction of efficient transport policies leads to an increase in inequality is an empirical question that needs to be addressed by designing and applying equity indicators. Chapter 8 discusses and provides practical guidance on how inequality should be defined and measured across individuals and households living in different regions and having different socio-economic characteristics. First, inequality measures, poverty measures and some alternative approaches for measuring accessibility as an important variable in the provision of transport infrastructure and services are defined. Secondly, two alternative approaches for addressing inter-generational equity considerations are presented and finally general recommendations for addressing equity are given.

In the first section of Chapter 9 some general guidance on both passenger and freight transport policy evaluation is given. It sums up the most relevant guidance and recommendations from the previous chapters for case study evaluation. In the latter section of Chapter 9 the given general guidance is reviewed with respect to how the guidance will be adopted especially in the SPECTRUM case studies bearing in mind the focus of each study, data and models on hand.

The first set of appendices consists of plain tables of results of previous studies on values of time, other cost components, values for the externalities etc.; also some examples for calculation are given (Appendices 1 and 2). In the following appendices the freight model MOBILEC and a model for road traffic accidents are described in more detail (Appendices 3, 4, 5 and 6). Finally, regarding equity and accessibility, some more profound descriptions and guidance for calculation are given (Appendices 7, 8 and 9).

2 The high level evaluation framework

2.1 Objectives, impacts and indicators

This section shortly links the work carried out in SPECTRUM by introducing the high level evaluation framework as the basis for the process of exploring how the impacts in practice should be treated and measured.

The SPECTRUM assessment framework is by its economic approach based on welfare economics. According to this approach impacts that can be monetised will be included in a CBA. Impacts that cannot be monetised will be included in a MCA or as part of a description based assessment. Some impacts have both a monetised part and a non-monetised part and thus need to be included in both.

Policy measures are introduced for achieving transport policy objectives. The SPECTRUM set of objectives, a list of impacts presently appraised and a comprehensive list of indicators have all been defined separately and presented in Deliverable 5 (SPECTRUM 2003). The linkage between objectives, expected impacts and indicators of these impacts are presented in Table 2.1 and Table 2.2 for passengers and freight respectively. The division of objectives and sub-objectives comply fully with the framework derived having the two main objectives of "Economic Efficiency" and "Equity". The three last columns of the tables give a note for the appropriate assessment method. The outcome of the assessment of the case studies will be presented in the form of Table 2.3 for monetised impacts (CBA) and Table 2.4 for non-monetised impacts (MCA).

In practice, we need in advance to determine which policy measure or package of measures best fulfils both the broad and specific objectives set in each particular case. We need either to compare all possible alternatives with each other or for instance use optimisation methods to find a suitable set of measures. The impacts are usually revealed through transport models and thus the characteristics and capability of the model used as well as the outcome of the model play a major role in the assessment process. The indicators presented in Table 2.1 and Table 2.2 are either indicators themselves or other model outcome from which the indicators are to be derived or calculated. In the assessment process it would be the change in the level of an indicator that we are interested rather than the absolute values.

Depending on the case study, all relevant impacts and their appropriate indicators should be included in the assessment. If it is self-evident that the policies tested will not have any effect on a specific indicator it is of no use including it. It might also be that there are such impacts that we cannot predict with the models available and thus the indicator becomes useless. However, if we presume the impacts to be important, we should try to overcome the problem for instance by using alternative indicators (even not so good) or by finding other methods to assess them, at least experts' opinion.

This report will give practical guidance how the impacts on transport are treated in the assessment procedure, what indicators to use for different impacts and finally how they can be measured and included in the assessment framework. The whole range of transport will be covered: both passenger and freight transport; urban, inter-urban and where relevant, rural transport; travel purpose or commodity groups, mode and time of day as well as all stakeholders involved in a transport system at each market level. In other words the framework covers international, national, regional and local transport systems with governments, regional and local authorities, producers, managers and operators as stakeholders and last but not least the consumers.

Table 2.1 SPECTRUM objectives, impacts and indicators for passengers

Objectives		Sub-objectives	Impacts on passengers	Indicators	Method *)		
					CBA	MCA	DA
Economic Efficiency	**1. Economic Efficiency** All modes; all market levels	Efficient production of all transport services	optimal potential and supply for mobility and transport (new infrastructure, service supplied)	modal split, service used (car-/person-km)	√		
	1.A Net user benefits for consumers	Improve accessibility at all levels (e.g. to services and work locations, economic nodes and gates)	low generalised cost, high mobility and accessibility	generalised cost, accessibility (travel time, distance, variable costs)	√		
	1.B Producers' surplus	Reduce congestion and eliminate bottlenecks	less congested traffic flows, low generalised cost	travel time (peak, off-peak travel times)	√		
		Improve reliability and quality of service for passengers both in domestic and international transport	high public transport service levels (incl. quality of fleet), good facilities for private car, high predictability	service level (accuracy, quality, comfort, etc)	√	√	
	1.C Net government revenue	Attain the government's revenue raising objective of transport sector as efficiently as possible		present value of finance, internal rate of return	√		
	1.D Efficiency in the rest of economy	Economise on tax payers' money		cost effectiveness	√		
		Use of revenues in an efficient manner		"	√		
		Minimise adverse effects on other markets for example labour market.		"	√		
	2. Environment and Health	Protect population and environment from pollution (local and regional), noise and vibration, and from other harmful effects of transport (visual intrusion etc.)	minimum harmful effects from traffic: pollution, noise, vibration, visual intrusion etc.	energy consumption (per vehicle -km), amount of pollution (CO_2, NOx, PM), noise levels	√	√	
		Protect valuable areas: green areas, cultural heritage sites, landscape and vulnerable areas		proportion of green areas			√
		Avoid urban sprawl and land take for transport purposes		land area taken	√	√	
		Reduce fragmentation (of settlements and habitats)		internal accessibility		√	√
		Promote health benefits from physical activity from non-motorised modes	increased physical activity	modal split, use of non-motorised modes (number of people and km)	√	√	√
	3. Safety and Security	Reduce traffic related fatalities and injuries	improved safety and health	number of accidents by type (per person and vehicle-km)	√		
		Increase security for passengers	improved security	customer satisfaction, statistics of criminal offence against passengers	√	√	√
	4. Economic Development	Ensure GDP growth		GDP	√		
		Reduce unemployment	labour market	unemployment rate		√	
	5. Liveability	Achieve positive external effects associated with social cultural and recreational activities		customer satisfaction			√

*) CBA Cost Benefit Analysis, MCA Multi Criteria Analysis, DA Descriptive Analysis

Table 2.1 continued: SPECTRUM objectives, impacts and indicators for passengers

Equity	**1. Economic Efficiency**	Promote equity and social inclusion	taxes, charges, subsidies	variations in accessibility, welfare	√		
		Promote desirable regional development	“	spatial variations in accessibility, welfare etc	√		
		Promote desirable distribution of benefits among social and income groups (e.g. specific groups like the mobility impaired)	“	welfare, customer satisfaction,	√		
	2. Environment and Health	Reduce depletion of non-renewable resources		use of non-renewable resources	√		
		Avoid climatic change due to human activity in the transport sector		CO_2	√	√	
		Promote biodiversity and protect vulnerable ecosystems		affected nature preserve areas	√		
	3. Safety and Security	Increase safety and security especially for vulnerable transport system users	improved safety and security	proportion of accidents and other incidents involving vulnerable transport system users	√	√	√
		Promote spatial equity		spatial variations in safety and security	√	√	√
	4. Economic Development	Ensure desirable regional growth	accessibility	inter-urban accessibility, regional equity		√	
	5. Liveability	Increase freedom of movement for vulnerable users	daily short distance (urban) trips	modal split and number of daily short distance (urban) trips		√	
		Decrease segregation of population by social, ethical, income etc.		level of segregation of population			√

*) CBA Cost Benefit Analysis, MCA Multi Criteria Analysis, DA Descriptive Analysis

Table 2.2 SPECTRUM objectives, impacts and indicators for freight

Objectives		Sub-objectives	Impacts on freight	Indicators	Method *)		
					CBA	MCA	DA
Economic Efficiency	**1. Economic Efficiency** All modes; all market levels	Efficient production of all transport services	optimal potential and supply for freight transport (new infrastructure, service provided)	modal split, service used (vehicle -/tonne-km)	√		
	1.A Net user benefits for consumers	Improve accessibility at all levels (e.g. to services and work locations, economic nodes and gates)	low cost, high accessibility	generalised cost, accessibility (travel time, distance, average return per ton-km per goods category)	√		
	1.B Producers' surplus	Reduce congestion and eliminate bottlenecks	less congested traffic flows, low generalised cost, easy border crossing	travel time (vs. uncongested time)	√		
		Improve reliability and quality of service for freight both in domestic and international transport	good and reliable facilities for freight, high predictability	service level (e.g. capacity utilisation, share of productive freight vehicle -kms, share of on-time deliveries, travel time variance)	√		
	1.C Net government revenue	Attain the government's revenue raising objective of transport sector as efficiently as possible		present value of finance, internal rate of return	√		
	1.D Efficiency in the rest of economy	Economise on taxpayers' money		cost effectiveness	√		
		Use of revenues in an efficient manner		"	√		
		Minimise adverse effects on other markets, for example labour market.		"	√		
	2. Environment and Health	Protect population and environment from pollution (local and regional), noise and vibration, and from other harmful effects of transport (visual intrusion etc.)		energy consumption (per vehicle -/tonne-km), amount of pollution (CO_2, NOx, PM), noise levels	√	√	
		Protect valuable areas: green areas, cultural heritage sites, landscape and vulnerable areas		proportion of green areas			√
		Avoid urban sprawl and land take for transport purposes		land area taken	√	√	
		Reduce fragmentation (of settlements and habitats)		internal accessibility		√	√
	3. Safety and Security	Reduce traffic related fatalities and injuries	improved safety	number of accidents per freight vehicle -km/tonne-km by type, proportion of accidents caused by freight transport	√		
		Increase security for freight transport	improved security	proportion of damaged / stolen cargo	√	√	√
	4. Economic Development	Ensure GDP growth	low generalised cost	GDP, generalised cost	√		
		Reduce unemployment	labour market	unemployment rate		√	
	5. Liveability	Achieve positive external effects associated with social cultural and recreational activities		customer satisfaction			√

*) CBA Cost Benefit Analysis, MCA Multi Criteria Analysis, DA Descriptive Analysis

Table 2.2 continued: SPECTRUM objectives, impacts and indicators for freight

Equity	**1. Economic Efficiency**	Promote equity and social inclusion	taxes, charges, subsidies	accessibility, welfare	√		
		Promote desirable regional development		spatial variations in accessibility, welfare etc	√		
		Promote desirable distribution of benefits among social and income groups (e.g. specific groups like the mobility impaired)		welfare, customer satisfaction	√		
	2. Environment and Health	Reduce depletion of non-renewable resources		use of non-renewable resources	√		
		Avoid climatic change due to human activity in the transport sector		CO_2	√	√	
		Promote biodiversity and protect vulnerable ecosystems		affected nature preserve areas	√		
	3. Safety and Security	Increase safety and security especially for vulnerable transport system users	improved safety and security	proportion of accidents involving vulnerable transport system users	√	√	√
		Promote spatial equity		spatial variations in safety and security	√	√	√
	4. Economic Development	Ensure desirable regional growth		regional equity		√	
	5. Liveability	Increase freedom of movement for vulnerable users	reduced adverse freight transport	amount of freight transport in populated areas		√	
		Decrease segregation of population by social, ethical, income etc.		level of segregation of population			√

*) CBA Cost Benefit Analysis, MCA Multi Criteria Analysis, DA Descriptive Analysis

2.2 Appraisal methods

The first stage of determining how objectives, impacts and their indicators should be included in the appraisal framework derived in Deliverable 5, is to separate the indicators into those that can be monetised and those that will necessarily be included in other ways. It is important to note that in a practical context it may not be possible to include all the objectives and sub-objectives listed in Tables 2.1 and 2.2 within the appraisal, as the data for the indicators may not be available from the models used, such as changes in welfare or income, appreciation of quality impacts and information provision etc. In these situations it will be important to utilise experts' opinions and survey data.

2.2.1 Monetary techniques

The Cost Benefit Analysis (CBA) is the most common technique for appraisal of impacts that can be monetised. It presents the net present value (NPV) for each of the stakeholder groups in the framework and a total. The analysis will be disaggregated by investment and maintenance costs, external costs, transport and spatial benefits and government revenue. Also the benefit cost ratio should be presented to provide an idea of whether the pricing measures will increase or decrease the benefits any more than the regulatory or physical measures that could be used to replace or complement them. The process will involve welfare analysis on all impacts resulting from the introduction of the package that can be monetised. The main restriction of using this method is that at present not all impacts can be monetised and included in a CBA and if these 'other' impacts are to be included in the assessment then an alternative method for doing so needs to be used. For this reason MCA and description based methods have been included in this appraisal framework.

Cost Effectiveness Analysis (CEA) is another monetary technique for appraisal. CEA can be conducted in the similar fashion to the CBA, in terms of producing monetised ranking of various projects or project implementation alternatives. CEA can be described as an analysis by which the alternative is identified that can be most efficiently implemented to reach a target level of social effects. Alternatively, it may be used to achieve a certain social objective (Wesemann 2001). The obvious advantage of CEA is that it can be used to rank alternatives in two dimensions: with respect to their ability to meet selected objects or with respect to their associated cost minimisation. However, the limitations are also apparent: The technique does not provide information concerning the socio-economic profitability of various alternatives but merely a ranking. In addition, when multiple criteria are set, the cost effectiveness cannot be calculated one-dimensional. However, also the CEA can be complemented by the use of non-monetary techniques.

2.2.2 Non-monetary techniques

The main reason for including an impact in the Multi-Criteria Analysis (MCA) is if it cannot be readily monetised, for example, certain qualitative impacts and information provision, given current up-to-date practice. However, the use of MCA requires that the impact can be valued in some scale, scored or ranked and that there exists a fairly common opinion of doing so. The MCA then encompasses several techniques to include the impact in the analysis (see SPECTRUM Deliverable 5). The main criteria for including the MCA facet in the SPECTRUM framework is to accommodate for those impacts that at present cannot be monetised and thus are often left with less consideration. If only feasible, by determining weights for the impacts, it will be possible in the MCA to present a score for each stakeholder and an overall score.

The rationale for using Descriptive Analysis (DA) is to cover impacts that would not necessarily be accommodated either by the CBA or MCA. There are many incidences in which the country appraisal framework uses descriptions to consider such impacts, for example in the cases of certain environmental, socio-economic and quality impacts.

2.2.3 Remarks on the appraisal methods

One of the constraints on the appraisal process is the data requirements and restrictions for particular models in their capability of producing sufficient outputs covering the various impacts. This will also depend upon the indicators, i.e. how they have been defined in order to reflect the objectives and their impacts. In some cases data will not be available to produce a comprehensive appraisal of all objectives for all practical cases. Where this happens it will be important to include experts' opinions, i.e. the descriptive analysis.

However, consistency will be achieved across the case studies, as basically the same set of impacts will be included in the CBA and MCA despite of the small differences in the data and definitions. The CBA and MCA methods will be completed as separate methods in the framework and will provide a basis for comparison across the case studies as they will be assessing the same impacts.

Impacts included only in the descriptive analysis are often very diverse in nature and thus difficult to measure or model properly. For this reason they are treated separately as "stand alone" supplement to the rest of the analysis.

2.3 Presentation of the results

The output presentation tables of the analysis (Table 2.3 and Table 2.4) have been designed to allow the data to be presented at both disaggregate and aggregate level. The methods are presented separately, but are considered simultaneously in the overall appraisal framework.

The results can be compared across projects, as the same impacts will be included under each individual method. It provides maximum flexibility, as it may be decided that the CBA facet will be used on its own or in conjunction will the other appraisal facets. At the most basic level the results can thus be presented as a single value for each of the methods:

- NPV (CBA)
- Ranking (CEA)
- Score (MCA)
- Descriptions

More detail should then be provided by differentiating by the stakeholder groups and by the individual components of the methods.

Table 2.3 Presentation of Results of CBA

(including all impacts that can be monetised)

Case study________________________	Urban / Inter-urban	Run no_____	Policy Package__________________

Model / Study area________________________	Assessment method________________	Assessment period____________	Discount rate_____

Impacts not included__________________________________	Why? ______________________________________

Present value of	**Consumers**	**Producers**	**Government**	**Non-users & Other markets**	**Row total**
Investment costs					
Maintenance costs					
User benefits					
Safety costs					
Air pollution costs					
Noise costs					
Equity impacts (welfare)					
Government revenue					
Other benefits					
Column total	Consumer Surplus	Producer Surplus	Present Value of Finance	Non-user Surplus + Indirect Costs	Net Present Value

For MCA, in addition to a CBA table, another output table for the non-monetised impacts will be needed. By assigning weights for the impacts and measures, using expert opinion for example, it will then be possible in the MCA to present row and column totals as in the CBA.

Table 2.4 Presentation of Results of non-monetised impacts in MCA

Case study_______________________	Urban / Inter-urban	Run no____	Policy Package__________________

Model / Study area_______________________	Assessment method_______________	Assessment period_____________	Discount rate_______

Impacts not included________________________________	Why? ____________________________________

Value, score or description of	**Weight**	**Consumers**	**Producers**	**Government**	**Non-users & External**	**Row total**
Equity impact indicator 1						
Equity impact indicator 2						
…						
Accessibility measure 1						
Accessibility measure 2						
...						
Column total						

For the final analysis the two tables have to be considered together. In addition, in order to give comprehensive results (e.g. for an external user such as a decision-maker) the full context and specific circumstances of the study should be described together with the appraisal results. The indicators and descriptions that should be included in the final presentation of the evaluation are very case specific but for most cases it can be recommended to present some specific study area characteristics and model results as well as changes in these in absolute values separately in a form of simple tables or graphs, for example such as:

- Specifications of the case study and the study area involved
- Demographics, car ownership etc.
- Total person-kilometres / tonne-kilometres
- Total vehicle-kilometres (in person car equivalents) / tonne-kilometres
- Total CO_2 emissions
- Modal split shares
- Benefit cost ratio.

Presentation of these characteristics in a visually simple and clear manner (see Minken et al. 2003 for guidance) helps the decision-maker and other stakeholders relating the appraisal results to a wider context.

Besides looking at the different appraisal methods, an important issue within the future work of the project is to investigate means of comparing between different case study outcomes. Therefore, in the case study appraisals the methods available will be looked at in more detail and their relevance compared within and across the studies.

2.4 Economic Development

2.4.1 Transport benefits and economic growth

An examination of the linkage between transport and the economy demonstrates that impacts may involve a number of different transmission mechanisms. In particular, it appears that the generated economic effects are more the result of indirect influences (such as changes in the feasibility/optimality of reorganisation/relocation changes) than direct implications of lower transport costs. These transport cost reductions can influence a broad range of elements, including:

- Regional patterns of commerce
- Incentives to invest/innovate by firms
- Productivity of production factors
- Potential for reorganising production processes
- Location decisions by firms
- Commuting and migration decisions of households and hence employment and consumption aspects

On the other hand several counter arguments are of importance, which may imply either reduced positive importance of transport for regional economic development or indeed negative impacts (e.g. due to the two-way road argument or the displacement of economic activity).

A number of measurement techniques are available covering mainly quantitative approaches with different degrees of complexity. Of particular importance for the development of complex appraisal frameworks for transport schemes methods such as

Computable general equilibrium (CGE) models, Land-use and transport interaction (LUTI) modelling and Geographical Information System (GIS) methodologies would be relevant given their detailed provision of information with the possibilities to take account of the spatial/sectoral and social distribution of impacts. The possibilities for integrated use of several measurement techniques such as GIS and LUTI could be considered further.

The identification of wider economic impacts from transport infrastructure schemes raises the important issue of whether these are already taken into account through the inclusion of the direct transport impacts from the project (e.g. through transport user benefits). Traditionally, cost-benefit analysts have held the position that wider socio-economic impacts, such as employment effects, of transport infrastructure schemes are already taken into account and would if included imply double-counting. This conclusion can be contested given the fact that it is based on an assumption that perfect competition holds for the economy as a reasonable approximation. SACTRA (1999) identifies the conditions in which the wider economic impacts are covered from the direct transport impacts:

- completeness of the transport appraisal in terms of covering all sources of transport costs including short and long run effects as well as correct valuation of the different benefit and cost elements;
- perfect competition conditions of the economy are present.

However, it should be noticed that it is not possible prior to empirical analysis to determine the sign of these wider economic impacts as it would depend on whether prices facing transport users and transport providers are larger or smaller than the marginal social cost of the activities. If the implementation of a transport scheme allows competitors to enter a previous monopolistic market then this would entail higher net-benefits with inclusion of wider economic effects compared to without inclusion of these impacts, provided there are no external costs/ benefits.

Transport system and economic efficiency

Transport has often been considered to be one of the backbones of the economic development. Therefore we should be able to derive some benefits from an improvement in transport systems' performance. These impacts may be called indirect impacts (Laird et al 2003, Mackie et al. 2001).

All producers in the economy (i.e. not only the producers of transport services) will benefit from the transport investments through increased opportunities to trade. This will take place through faster access and better use of the network because of the new investments. To analyse the impact in greater detail, a number of options are available. The first option is to develop some form of gravity model for industrial location, which would calculate the impact of new transport investment as a function of access and physical distance for the industries located in the area where the investment takes place. The second option is to gather survey information of the impacts on the industries. This may be a more productive way to analyse the impact on producers, as simply relying on the location of local industries leaves the question of their trading partners unanswered. This means that we will not be able to generate any information regarding the trade between the producers in the area and their business partners. There may emerge new business patterns and partners that would not have realised in the absence of the new transport investment. Furthermore, more complex approaches such as Land-Use and

Transport Interaction (LUTI) models and Computable General Equilibrium (CGE) Models are also possible approaches.

We recommend that the calculation of producer benefits should be carefully considered, but, where appropriate, added to the transport CBA to illustrate the broader benefits from a transport initiative. Values and magnitude should be evaluated based on the survey or a model to capture the impacts in a particular case. Relying on literature is not likely to give any significant insights in the analysis, as the impacts are context-specific.

Many impacts are reflected back to the transport network via other markets, like employment and regional development.

2.4.2 Present models and CBA

Cost benefit analysis based on partial equilibrium transport models (the types of model that are used in most transport studies, also in the SPECTRUM case studies, typically employing a nested logit transport demand model and assignment onto a network representing "supply") will not be able to identify behavioural responses that may lead to economic growth. This is simply because they abstract from any other economic impacts than those occurring immediately in the transport markets. It might however be conjured that transport improvements will play a part in making other markets more efficient, creating new possibilities to explore economies of scale in firms and economies of agglomeration, etc. If this is seen as reasonable, the size of the welfare gain as measured by the transport CBA might be taken as a rough indicator of the economic growth potential of a scheme.

Existing knowledge on the relation between transport improvements and economic growth has been surveyed by SACTRA (1999). The conditions in which a transport improvement is likely to have efficiency impacts over and above the gains as measured by the transport CBA are summarized in the SACTRA report and are reproduced here as Table 2.5.

In this table, CBA signifies transport cost-benefit analysis as currently carried out according to official UK guidance and CBA** signifies a theoretically perfect CBA which captures all impacts in the economy and all transport externalities, assuming, however, that the economy outside transport is perfect. B > 1 and B** > 1 indicate cases where total economic benefits exceed transport benefits in relation to CBA and CBA** respectively, and B < 1 and B** < 1 indicate the opposite. It is seen that there will be additional benefits as compared to an ordinary CBA if prices exceed marginal costs in the transport using sectors or if prices equal marginal costs in these sectors but exceed long-run marginal social cost in the transport sector. Conversely, the transport CBA tends to overstate benefits if prices in the transport using sectors are too low.

Table 2.5 is however still a long way from indicating when economic growth impacts might actually occur. For instance, the scheme's transport investments might have to be financed in ways that counteract the wider efficiency gains, or might crowd out private investment with even better chances of inducing growth. And in essence, growth is a dynamic concept and might not be helped solely by improving static economic efficiency.

Table 2.5 Imperfect Competition and External Costs Effects on the Evaluation of Transport Projects

	Transport-Using Sector		
Transport Sector	**p < mc (pmb > smb)** *subsidies* *labour market clears*	**p = mc (pmb = smb)** *perfect competition* *labour market clears*	**p > mc (pmb < smb)** *imperfect competition* *w > msc labour in assisted areas*
p < lrmsc *adverse externalities* *congestion* *user charges too low*	**B < 1; B** < 1** Negative external effects exacerbated by overvalued output in transport-using sector; may be substantial benefits from reducing use	**B < 1; B** = 1** Traditional external effects case; no offset from transport- using sector; conventional CBA overestimates total economic benefits.	**B = ?; B** > 1** Transport and transport-using benefits are of opposite sign. CBA** is appropriate on transport sector but not on implications of imperfect markets.
p = lrmsc *no externalities* *optimal capacity* *user charges correct*	**B < 1; B** < 1** Subsidy to transport-using sector means total economic benefits < transport benefits Conventional CBA overestimates the value of transport improvements.	**B = 1; B** = 1** No market failure. Economic benefits equal transport benefits; conventional CBA fully adequate.	**B > 1; B** > 1** Extra output in transport-using sector and job creation in assisted areas; total economic benefits exceed transport benefits.
p > lrmsc *positive externalities* *spare capacity* *user charges too high*	**B = ?; B** < 1** Transport benefits and transport-using benefits are of opposite sign for conventional CBA. Indeterminate case.	**B > 1; B** = 1** No market failure in transport-using sector; standard case for expanding transport usage by reducing user charges.	**B > 1; B** > 1** Spare capacity in the transport sector and transport benefits understate total economic benefits; reduction in user charges may give big welfare gains.

Notes: **pmb** = private marginal benefit; **mc** = marginal cost; **smb** = social marginal benefit; **lrmsc** = long run marginal social cost; **p** = price

Source: SACTRA (1999) and Goodwin and Persson (2001).

3 Impacts on passengers

3.1 Introduction

Out of the several categories of impacts falling on the passenger (see Table 2.1) this chapter only discusses assessment of impacts of economic efficiency i.e. net user benefits for consumers derived from transport policy measures. External impacts (accident risk, pollution, noise and congestion) and equity are treated separately in chapters 6-8. Net user benefits comprise time costs, variable and fixed monetary costs of a journey and other benefits that the user finds valuable during the journey. These components are used to form a generalised cost function. Variable user costs are those costs which the transport system user experiences as direct out-of-pocket costs during the journey and the variable part of other costs (costs like investment, maintenance etc.) whereas fixed costs are costs that the user or owner has to pay regardless of the amount of travel. In addition, journey reliability, quality, security and information provision have an impact on generalised cost, but these impacts are very difficult to build into a transport model and thus are seldom available as model outcome. Mobile services and the Internet have made it possible to introduce new kind of costs for the traveller, e.g. in the form of pay services of travel information.

It should be noted, that the costs functions imbedded in transport models represent average user behaviour in the transport system the specific model describes. Thus the values derived from a model may be dependent on other characteristics or factors of the model although the aim of the model is to reflect the actual transport system as well as possible. Therefore, the model values of costs are not always suitable as such for evaluation purposes.

The cost of congestion also falls on the traveller in terms of increased travel time and extra fuel consumption for car and thus in practice, looking at a transport model, it may not be separated or it is not practical to separate it out of the other travel costs. Therefore, although the cost of congestion is discussed in Chapter 7 of externalities, some results of values of time due to congestion are presented together with other time value components in this chapter.

There can be some variation in categories in the cost-benefit analysis for passenger transport studies depending on the nature of the study, urban or inter-urban or even international etc. The modes considered depend on the case study but should be divided at least in three groups, walk and cycle, public transport and car for urban trips. In inter-urban travel all relevant modes should be separated. The purpose should be categorised in the minimum for business vs. private trips but preferably separating commuting trips from other private trips. In addition, sometimes also fixed costs need to be analysed as policy measures may have an effect on for example car ownership.

Section 3.2 discusses impacts on transport demand and how these should be included in the assessment analysis. Following this, the assessment framework for passengers is presented in Section 3.3 together with the elements of the generalised cost for a passenger. Section 3.4 discusses the importance of distinguishing different person groups in the analysis and Section 3.5 advices how to include the generalised cost benefits in the CBA.

In Section 3.6 at first some results and distinct values based on EU and other European studies of valuation of time of passenger transport are presented. Secondly, some U.S. recommendations based on research carried out both in Europe and in the USA are presented together with summaries of results and findings from several studies to give a wider scope of possible values and valuation methods. Section 3.7 examines the evaluation of other cost components such as variable and fixed out-of-pocket costs. Conclusions and recommendations are outlined in Section 3.8.

3.2 Impacts on transport demand

The effects of introducing a transport policy measure or a package of measures are normally studied in advance by using transport models and knowledge from implementations elsewhere. In addition to the changes in mode and destination chosen, travel time and travel costs due to the new policy, the model should also

- reflect changes in trip frequency; to make a trip or not for that purpose or even change purpose. (Note that this does not necessarily mean that the purpose of the initial trip is not fulfilled. The alternative may be to shift the trip to another time, consolidate trips, or meet the need in another way, such as by using telecommunications or a delivery service to replace a special vehicle trip.);
- reflect changes in trip timing (changes between peak – off-peak);
- take account of induced trips e.g. due to improved accessibility; and
- reflect changes in car ownership and possibility to use car.

3.3 Generalised cost of a trip

The generalised cost of a trip or journey is composed of several time as well as several variable cost components. Depending on the transport system and specific circumstances of the study in terms of urban and inter-urban transport, and where relevant, rural transport, there exists great variation in elements to be included in the appraisal. In addition to the different modes of transport the values of time components and variable costs usually depend on the purpose and the particular circumstances of the trip.

Regarding modes there are some obvious differences of urban and inter-urban contexts. Air and sea travel are clearly inter-urban modes along with inter-urban rail and sometimes coach, too. In an urban context these modes would not be included and instead the significance of the bus would be more prevalent. In addition, the rail mode has highly different functions in different urban areas as for the variation in provision of underground systems and local rail as well as tram and light rail.

Below is a common list of time and cost components for the generalised cost calculations. In each case study, a specific set of components will be used depending on trip category (urban-interurban-rural) and modes relevant to the study.

Time components

- In vehicle time
- Walking time
- Access/egress time
- Waiting time
- Transfer time
- Schedule delay time
- Concealed waiting time
- Search time for parking
- Time lost due to congestion and unreliability

Variable costs, out-of-pocket costs

- Public transport fares (concessionary fares)
- Fuel price
- Parking charges
- Congestion charging
- Road pricing (road and bridge tolls, distance based tolls)

Costs that are partly variable, partly fixed (the variable part consists of such costs that are related to the amount of travel and fixed part is the cost user has to pay regardless of use)

- Vehicle investment cost
- Vehicle maintenance cost
- Vehicle taxes, fees and insurance

Other costs

- Subsidies, compensation

Information provision

Quality, level of service

Security

Definition of components

Travel time components

In vehicle time is the time spent travelling in the vehicle. *Walking and cycling times* are also considered to be 'in vehicle time' when these modes are used as the main mode.

Access/egress time is the time in origin to reach and in destination to leave the main mode of transport. The concept of access/egress time is somewhat unsteady. Normally it means walking or cycling time to the stop of the first public transport mode or car park and in destination accordingly. Sometimes, especially in long distance travel, it can mean the total time to and from the main mode, for instance access time to airport by car, taxi or public transport.

Waiting time is the time spent waiting for a public transport vehicle, normally counted as half of the headway but especially on low frequency connections maybe cut to a certain maximum. (See concealed waiting time)

Transfer time (in some cases also *terminal time*) is the time used for transferring line or mode excluding waiting time.

Schedule delay time is the extra time due to unreliability of travel times (deviations from the expected travel time)

Concealed waiting time is the time between a person's desirable and the worthwhile leaving time e.g. at home or work place. This occurs only in connection with urban low frequency public transport and in inter-urban travel by public transport modes rail, bus, air and sea and more commonly in rural public transport. (Holmberg, 1977)

Search time for parking is the time spent looking for an empty parking space.

Time lost due to congestion and unreliability is the time spent in congested traffic situations or lost due to presumption or fear of congestion or other negative incidents.

Variable, out-of-pocket costs

Public transport fare is the cost of a single journey according to the ticketing system in use. The distribution of ticket types (one-way, return, season etc.) by purpose of journey should be used in calculating the cost of a single journey. Concessionary fares can also be taken into account, e.g. in person group division.

Fuel price is the price consumer pays for a litre of fuel including taxes.

Parking charge is the single payment for the parking at the trip destination or a share of a prepaid periodic payment for a parking place.

Congestion charging and road pricing, road and *bridge tolls and distance based tolls* are direct or prepaid costs for car and sometimes separately for car passengers as well. They are similar to public transport fares and are treated accordingly.

Costs that are partly variable, partly fixed (the variable part consists of such costs that are related to the amount of travel and the fixed part is the cost user has to pay regardless of use).

Vehicle investment cost is the capital cost of a vehicle including tax (the variable part should be allocated to a unit element of a trip e.g. kilometre).

Vehicle maintenance cost composes of all other costs of having and using a vehicle such as costs of regular service, spare parts and repair, tyres, garage etc. (the variable part should be allocated to a unit element of a trip e.g. kilometre).

Vehicle taxes, fees and insurance are additional charges imposed on the vehicle (usually independently of use and thus fixed costs). (If there exists a variable part it should be allocated to a unit element of a trip e.g. kilometre.)

Other costs

Subsidies, compensation in this context is an amount of money paid directly to the user for some special reason e.g. disability and should be counted per trip or per kilometre travelled.

Information provision, quality, level of service (other than frequency which is related to waiting time), security and user friendliness of the system have an effect on the generalised cost of a journey but are not generally considered as stand alone components of the generalised cost but more like reinforcement or lessening to the effect of another component. The reason for this is that it is very hard to set a separate overall value for each of the effects. Their effect rather creates a feeling of satisfaction or dislike that often is incorporated to the value of corresponding time component of the mode concerned. However, there are studies where these effects have been measured and valued separately but the values are fully case specific as they depend heavily on the transport system and the specific circumstances of the trip. In practice this means that people are willing to pay for quality, comfort, security etc. but the value is so case specific that it commonly is included in the value of time in the specific circumstances.

3.4 Passenger groups

The transport system impacts on a passenger depend in addition to the personal attitudes (attitudes towards the environment, recycling, health, sports etc.) and mobility needs more generally on basic characteristics of the person and on the person group he/she belongs (gender, age, family size, etc., see below).

Depending on the circumstances of the study or the characteristics of the model used population is divided into groups and even subgroups according one or several of the following characteristics:

- Gender
- Age
- Income or household income
- Activity of a person; employment, school, student, retired etc.
- Phase of life of the household (single adult, adult couple without children, adult couple with children under school age, adult couple with school children etc.)
- Car ownership
- Possibility to use car (usually three groups: car always/sometimes/never at own disposal) (Jarvi-Nykanen & Himanen, 1995)

All these groupings give prospects about their mobility needs and restrictions that apply. Thus separating different person groups for the assessment gives us more accurate results than aggregation over population because of reduced variation.

Especially in SPECTRUM and other projects that study effects of transport policy measures the use of person group based valuation compared to only mode specific valuation is essential because the effects comprises shifts from one mode to another and other changes in mobility behaviour inside a person group. Taking an example of the inversion, if we use only mode specific values of generalised cost components we change an individual's cost values as he changes mode in consequence of the introduced measure whereas using person group based valuation they are retained.

Usually it is not possible to use very detailed groupings because there is no data available or the models do not respond. In addition, the groupings presented partly or even strongly correlate with each other and it is recommended to avoid high correlation because correlating groupings present same characteristics (for example both car ownership and possibility to use car correlate with income as well as person's activity; age correlates with having a driving licence etc.) The easiest grouping available nearly in all circumstances is the grouping according to gender and age divided into at least three groups: children, people of active working age and elderly.

In addition to these groups there are several special groups that should be separately addressed mainly for equity reasons, such as people with reduced mobility and vulnerable road users like people walking, biking, using roller skates etc.

3.5 Calculating economic efficiency for passengers

The impacts of implementing transport policy measures on net user benefits for a passenger can be measured as changes in the generalised cost which are calculated using indicators of the passenger transport system: changes in travel time and distance by mode and purpose. Measures may also have an effect on car ownership, car make and design and the whole fleet in general, e.g. in form of a shift towards more fuel efficient cars, smaller, bigger or newer cars etc.

The cost to consumers, the value of the travel they forego, can be roughly estimated by applying the rule-of-half from consumer surplus theory. The rule-of-half is a good approximation to the real user benefits for small changes in generalised costs of passengers and assumes implicitly that there is a linear relationship between the cost of travel and demand i.e. the demand curve resembles a straight line. If this is not the case, and the demand curve is convex to the origin, then the rule of a half will tend to overstate the benefits (Figure 3.1). Another possibility is to use the transport model parameters (logsum) as a tool for measuring the benefits.

The rule-of-half has the additional advantage over other more complex methods that it can be decomposed further into benefits concerning each of the additive terms of generalised cost. That way, time saving benefits and money saving benefits can be analysed separately for each travel relation and for all travel relations aggregated. Furthermore, if the model contains other terms of cost or benefit that are added to generalised travel costs in order to influence destination choice, the benefits of changes in these are also separable from the benefits of changes in travel costs. In that way, benefits associated with price changes or other supply changes at the destinations, changes in zonal attractions, can be separated out. (Minken, 2002 and Sugden & Williams, 1978)

More generally, especially if only transport impacts are considered and over the short-run, travel time savings can be calculated using consumer surplus (i.e. the rule-of-half). If also land use changes are included and over the long run, increased travel speeds will tend to change land use and travel patterns, resulting in a different set of consumer and economic impacts (Newbery, 2002, Simmonds,2001). However, the SPECRUM case studies address transport impacts using transport models only and thus it is justifiable to use the rule-of-half.

The benefit of induced traffic, when added to the cost savings on existing traffic, yields a measure of total benefit i.e. the change in transport consumer surplus. In Figure 3.1, where G^0 and G^1 represent generalised cost in the do-minimum and tested strategy and T^0 and T^1 travel volume respectively, the net benefit equals the rectangular area A (cost savings on existing traffic) plus the quasi-triangular area B (induced traffic benefit).

There are two interpretations of the rule-of-half. Using the above definition of net benefits we get

$$UB = \left(G^0 - G^1\right) * T^0 + \frac{1}{2}\left(G^0 - G^1\right) * \left(T^1 - T^0\right) \qquad (1)$$

but the area A+B can also be expressed as

$$UB = \frac{1}{2}\left(G^0 - G^1\right) * \left(T^0 + T^1\right) \qquad (2)$$

The first equation can be interpreted as "the net benefit is the sum of full value of change in generalised cost assigned to the current users and only half of the value assigned to the trips gained or lost". The second form of the equation tells that "the net benefit should be calculated for the average amount of travel in present and tested strategy situations" or in other words "half of the monetised benefit should be assigned to the current users and half to the users according to the tested strategy".

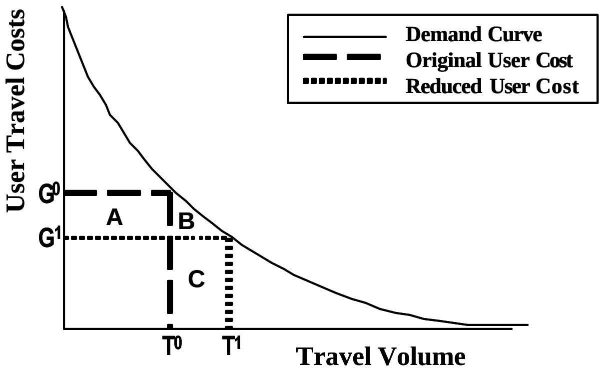


Figure 3.1 Vehicle Travel Demand Curve Illustrating the Rule-of-Half.

The total user benefit UB is the sum of UB(T) and UB(Att).

1. Benefits from generalised cost changes UB(T)

$$UB(T) = \frac{1}{2}\sum_{i,j,m,p,t}\left(G^0_{ijmpt} - G^1_{ijmpt}\right)\left(T^0_{ijmpt} + T^1_{ijmpt}\right)$$

2. Benefits from changes at the destinations UB(Att)

$$UB(Att) = \frac{1}{2}\sum_{i,j,p,t}\left(w^1_{jpt} - w^0_{jpt}\right)\left(T^0_{ij*pt} + T^1_{ij*pt}\right)$$

where
- superscript 0 and 1 denotes the do minimum and tested strategy, respectively;
- indices i, j , m , p, t denotes origin (residential zone), destination, mode, trip purpose and time of day in that order, and * denotes summation over the index;
- G is generalised cost, T is the number of trips;
- w is an index of the attractivity of a destination with respect to a trip purpose and time of day.

The main idea of an economic calculation of user benefits as clearly seen in Figure 3.1 is to include all changes in the calculation i.e. all areas A, B and C in the figure. The idea comes clearly up in the rule-of-half formula itself as well. Benefits or losses for the user only occur when some element in the generalised cost changes. For instance, if public transport frequency is substantially improved and it gains more passengers from private car users the benefits are only calculated from shortened public transport waiting time, for both 'old' and 'new' passengers because there are no changes in conditions for car. But, if due to less cars also car speed increases, the time benefit will be calculated taken account of both 'old' and 'new' car users (note: new is here less than old). For more discussion on the rule-of-half and other methods see (Minken & al. 2003).

Applying the rule-of-half in reverse, we can assume that a reduction in vehicle travel that results from a marginal price increase causes a net reduction in total value to consumers equal to half the price increase. Thus, for example, if kilometre-based vehicle insurance results in a 10% reduction in vehicle travel for a 70 euro average annual savings to users, the travel forgone can be estimated to have been worth 35 euros to users. Similarly, travel foregone as a result of a 6 cent per kilometre distance based travel charge can be estimated to have an average value to consumers of 3 cents per kilometre.[1]

3.6 Evaluation of time components

3.6.1 Introduction

For a uniform group of persons there should not be significant differences in values of time between the modes but there is empirical evidence that auxiliary components of travel related to a mode, such as comfort of travel, e.g. seat availability and tidiness, information provision, surroundings for waiting, expected congestion, perceived security etc. affect the value of travel time. This implies the use of different values for each mode when available as long as the auxiliary components are not valued separately. On the other hand, values may differ due to aggregation of person or purpose groups, as is often the case due to lack of more specific information. For example, if according to a field survey the values for in-vehicle time for bus and train

[1] The Rule-of-Half was validated by modeling by Greig Harvey and Michael Cameron in the latter's *Efficiency and Fairness on the Road*, Environmental Defense Fund (Oakland, CA), 1994. That report concluded that an 11% reduction in VMT (vehicle miles traveled) would eliminate only 5% of the aggregate value of travel. The reduction in VMT was estimated to result from an assumed 5¢/mile charge in passenger travel in Southern California.

greatly differ it is either evidence of differences in person or purpose groups using the modes or differences in comfort and other conditions of travel.

Household income, car ownership as well as a person's activity are usually highly correlated and have an effect on mode choice and valuation of time. In practice, if trip purposes are aggregated the value of travel time by air is surely much higher than by train, but if we introduce a grouping by purpose, income or activity, the differences should nearly vanish.

With the evidence given the values of time are very case specific depending on income, cultural, transport system and many other differences regarding the location and circumstances where the journey is made. Therefore, if local studies exist, it is highly recommended to use these values. In addition, most transport models use implicit values of time, so called behavioural values as they represent a person's behaviour in the transport system the model describes. However, sometimes these values represent only a part of the actual value as the other part is underplayed by the users and does not affect their behaviour, and thus does not show up in the model. It might also be that the level of costs throughout the model is either too high or too low and therefore the model values should be used with caution.

Below and in more detail in Appendix 1, we give an overview of findings and results of some extensive studies for use as comparison and reference material for the case studies. As the values of generalised cost components are related to monetary welfare i.e. GDP and income, the absolute values presented in the studies are not important, instead the relations between the different components are more useful. Some of the results presented are already in the form of factors related to another component.

Both revealed preference (RP) and contingent valuation (CV) approaches elicited in terms of willingness to pay (WTP) or willingness to accept (WTA) have been used for extracting values of time. Recently, the CV approach has become widely accepted in the context of value of time studies. Empirical evidence from the UK shows that CV estimates of values of time are smaller than, but relatively close to, RP estimates of values of time (Wardman, 2001 and 1997). For up-to-date values of time for each of the time component the following EU projects have been studied: UNITE, MC-ICAM, PROSPECTS and PETS; and in appendix also SCENARIOS and STREAMS. In addition, recent work of Wardman (2001) and Bruzelius (2002) has been referred as well as the Victoria Transport Policy Institute Handbook (2003) and guidance of U.S. Federal Aviation Administration, FAA (1998). A short summary of values and findings according to these studies is presented here.

3.6.2 European studies on VOT

UNITE

The UNITE-project (2003) and further the MC-ICAM-project (2003) have discussed the values of different time components of all modes in great detail. General findings from the UNITE-project (UNITE D7, D15, 2003):

- Empirical evidence suggests that the value of travel time saving for commuting is higher than for other private travel purposes. However, the differences seem to have decreased over time in modern societies.
- Most evidence on values of time relate to urban travel, where values are usually around 50 percent of the average wage rate (in-vehicle time).
- The UK, Swedish and Norwegian value of time studies suggest that values of travel time savings are significantly higher for inter-urban travel than for urban travel. Values of travel time saving for air travel are significantly higher than for other modes.
- There is evidence that components of travel time related to a mode, such as auxiliary travel, wait and transfer times, are valued more highly than in-vehicle time. The variations in the values seem to relate to the supply factors. (UNITE/MC-ICAM suggests a factor of 1.5 for delay and congestion and a factor of 1.6 for auxiliary time, wait and transfer.) Comfort of travel, e.g. seat availability while travelling with public transport or congestion on road network affects value of travel time.
- To the extent that it has been possible to describe reliability, it has been valued rather highly compared to in-vehicle time in most studies.
- There is vast evidence that values of time saving increase with income but less than proportionally.

The recommended monetary values of in-vehicle time of UNITE/MC-ICAM are presented in Table 3.1 and the factors for comparison and transfer between these values and national values are included in Table 3.2. (Comparison between UNITE and other values of time is given in Appendix 1.1.)

Table 3.1 UNITE and MC-ICAM values of time for passenger transport, Euro in 1998

Passenger transport, euros per person-hour	**UNITE values [1)]** **€/h**			**MC-ICAM values** **€/h**		
	Business	Commuting	Other purposes	Business	Commuting	Other purposes
Car, urban	21.00	6.00	4.00	21.00	6.00	4.00
Urban public transport	21.00	6.00	4.00	21.00	6.00	4.00
Car, inter-urban				21.00	7.00	5.00
Coach	21.00	6.00	4.00	21.00	6.00	4.00
Inter-urban rail	21.00	6.40	4.70	21.00	6.50	5.00
Air traffic	28.50	10.00	10.00	29.00	10.00	10.00

1) UNITE does not differentiate between urban and inter-urban values for car
Source: MC-ICAM D3 (2003)

Table 3.2 Factors to transfer UNITE/MC-ICAM recommended values to national values of time in euros

Country	GDP/Capita at € 1998 PPP	Transfer factor
UNITE/MC-ICAM	*22 150*	*1.000*
Austria	23 900	1.079
Belgium	23 677	1.069
Denmark	25 459	1.149
Finland	21 833	0.986
France	21 132	0.954
Germany	23 010	1.039
Greece	14 171	0.640
Ireland	23 194	1.047
Italy	21 531	0.972
Luxembourg	37 491	1.693
Netherlands	24 141	1.090
Norway	27 391	1.237
Portugal	15 891	0.717
Spain	17 223	0.778
Sweden	21 799	0.984
Switzerland	27 091	1.223
United Kingdom	21 673	0.979
Hungary	10 470	0.473
Estonia	9 193	0.415

Source: UNITE (2001), MC-ICAM D3 (2003)

FATIMA and PROSPECTS

The aim of both FATIMA (2000) and PROSPECTS (2003) projects were to find the best policy package for the targets set under certain constraints. The solutions were found using transport models and optimisation methods. The values of time used in the projects as well as kilometre based values for some externalities are shown in Appendix 1.4.

British Studies

Wardman (1998, 2001) has analysed and summarised over a hundred British studies of time values. The values in Wardman's research are based on behavioural values of several integrated studies of time values in transport, mainly for estimating values for public transport. A summary of ranges of values of in-vehicle time (IVT) presented in Table 3.3 and more detailed results can be found in Appendix 1.2. The values are expressed in year 2000 prices and segmented by the key variables of user type, journey purpose and whether the context is one of urban or inter-urban journeys given that the overall average will be strongly influenced by the composition of the sample. Two sets of figures are given according to the elasticity used to account for differences in real GDP per capita across values. One adjustment uses an elasticity of one (1.0) as used by DETR (Department of the Environment Transport and the Regions, UK, now DfT) in its recommended procedures. The other adjustment involves an income elasticity of 0.5, in line with cross-sectional evidence from the British value of time studies for the past twenty years.

Table 3.3 Overall values of in-vehicle time (converted from UK pence per minute to Euro per hour, in 2000 1£ = 1.6€)

		Income Elasticity =1.0	**Income Elasticity =0.5**	
Context	**Mode**	**Mean €/h**	**Mean €/h**	**Sample**
Urban Commute	Car	5.8	5.3	64
	Bus	4.0	3.6	17
	Rail	6.9	6.0	17
	Underground	8.8	7.9	5
Urban Leisure	Car	6.2	5.6	73
	Bus	2.5	2.3	22
	Rail	6.2	5.5	14
	Underground	7.0	6.2	16
Urban Business	Car	12.7	11.2	11
	Rail&UG[1)]	18.4	17.1	8
Urban Other	Car	6.1	5.6	84
	Bus	3.1	2.8	27
	Other	6.1	5.3	29
Inter-urban Commute	Car	10.1	9.6	11
	Rail	12.1	11.0	21
	Other	8.7	7.4	9
Inter-urban Leisure	Car	8.8	7.9	23
	Rail	12.8	11.5	44
	Air	74.1	71.2	4
	Other	11.2	9.6	8
Inter-urban Business	Car	17.6	16.9	16
	Rail (1st class)	30.9 (50.2)	28.1 (44.2)	34 (17)
	Air	86.6	79.1	12
Inter-urban Other	Car	7.1	7.1	10
	Rail	16.9	14.7	18
	Other	8.3	7.3	15

1) UG=Underground
Source: Wardman 2001

The values presented by Wardman are fairly close in magnitude to the recommendations of UNITE and MC-ICAM although his results are derived through a modelling exercise including various studies over a long time period and using several different methods. Most diverging are the low values for bus mode and high for air mode.

DETR recommended values of time (2001) are shown in Table 3.4. These are behavioural values adjusted to 2000 prices and income using the recommended income elasticity of one, hence directly comparable with those in Table 3.3. Here inter-urban and urban contexts have not been separated but there is great difference in values for business car and underground trips to Table 3.3, whereas the value for rail is closer as well as the value for non-work trips.

Table 3.4 DETR values of time (converted from UK pence per minute to Euro per hour, 2000 1£ = 1.6€)

Purpose	**€/h**
Business – Car Driver	38.1
Business – Rail	55.0
Business – Underground	46.2
Non-Work	8.2

Source: U.K. DETR 2001

Wardman's findings regarding the British values for in-vehicle time indicates that:

- Inter-urban trips have generally somewhat higher values than urban trips
- Business trips have higher values than trips for other purposes (the employee's rather than the employer's willingness to pay).
- For urban trips, commuting journeys have higher values than leisure trips for all modes other than car.
- For inter-urban trips, there is little difference between the values of time for commuting and leisure.
- The values of time vary quite substantially according to the mode used.
- For urban journeys, underground users appear to have the highest values.
- Air travellers have the highest values amongst inter-urban travellers. Bus users have the lowest values.
- The figures seem to indicate that rail users have higher values than car users, particularly for inter-urban trips, although there may be a distance effect at work here since inter-urban rail trips tend to be longer than inter-urban car trips.
- As far as non-work travel is concerned, the DETR recommended average value seems to be far too high for urban trips yet too low for inter-urban trips.
- Across all trips, however, the non-work value compares favourably with the large amount of evidence. Clearly, the recommended value bears little resemblance to the values by mode, but this is a consequence of using an equity value.

Values of walking time and public transport waiting time in proportion to the in-vehicle time (IVT) are presented in Table 3.5. For inter-urban travel an overall value is given because of the small sample size. For waiting time values it does not make sense to segment the urban values by journey purpose. Most of the values are based on stated preference research (SP) and hence the values might be somewhat lower than those of revealed preference values (RP). Especially the value of waiting time is particularly strongly influenced by whether it is obtained from RP or SP models. The values of waiting time represent actual waiting time and are derived from a sample of public transport users only. Full results can be found in Appendix 1.2.

Table 3.5 Overall in-vehicle time factors of waiting time and walking time

Context	Mode	Purpose	Waiting time		Walking time	
			Mean	Sample	Mean	Sample
All	All	All	1.76	62	1.68	183
Urban	Car	All	2.06[1)]	30		
		Commuting			1.37	29
		Leisure			1.74	25
		Other			1.55	34
	Bus	All	1.59	11		
		Commuting			1.67	10
		Leisure			1.66	13
		Other			2.02	13
	Other	All	1.17[2)]	11		
		Commuting			1.99	29
		Leisure			1.97	9
		Other			1.37	8
Inter-urban	All	All	1.70	10	1.51	13

1) Park&ride
2) Underground
Source: Wardman 2001

Wardman's findings regarding the values for waiting time suggest that:

- Overall the factor of waiting time is little different to the widely used recommendation of twice the value of IVT.
- Underground users appear to have relatively low values of wait time.

Wardman's findings from the values for walking time:

- For urban travel, the factors appear to be lower than the convention of using twice the IVT value, but otherwise, there seems to be little pattern in the average values.
- The inter-urban values on average fall well short of two, indicating that walk time is relatively less important on longer journeys.

Wardman also presents mean values of headway relative to the in-vehicle time. The headway is normally used to represent waiting time, especially for high service frequency (a half of the headway), but it can also be interpreted to represent the effects of schedule delay. In addition, according to the method it was possible to state values for headway for users of all modes whereas waiting time covered only public transport users.

The overall in-vehicle time factor of headway is less than half of that for waiting time, 0.77 versus 1.76, which means that people are prepared to use time tables and plan their trips ahead on routes of lower frequency. It can also be seen that on frequent and familiar trips e.g. commuting trips the headway is less important than on less frequent trips. This may be due to the feeling of security as they know the trip by heart and nothing on this route comes unexpectedly. For urban trips the headway factor tends to be larger and for inter-urban trips smaller than the factor for waiting time. (See Appendix 1.2 table 5 for full results.)

Other European studies

In recent studies (Mackie, Jara-Diaz and Fowkes, 2001 and Bruzelius, 2002) regardless of their grounds there has been more consensus in that business travel time savings should be valued on the basis of employer costs only i.e. to use the gross of tax wage rate (plus labour-related overheads) as the relevant commercial value of business travel time savings. Quoting Mackie et al.: “There are swings and roundabouts in this – some travel time savings may go into leisure rather than work, some travel time may be productive (so that care is required in modal split studies where productivity on rail or air is higher than on car), but on the other hand the value of the marginal product may on average exceed the wage rate." (Mackie, Jara-Diaz and Fowkes, 2001)

In PETS (1999) the weights presented in Table 3.6 separately for business and private purposes were suggested for passenger car trips. The reliability ratio is discussed more thoroughly in Section 3.6.5.

Table 3.6 Weights for journey time components with respect to IVT in PETS (1999):

	Business	Private
Weight for Wait time	1.31	2.0
Delay/late time	1.16	1.5
Reliability ratio	1.0	1.0

Source: PETS 1999

3.6.3 US recommendations on VOT

Victoria Transport Policy Institute Handbook

Various studies have investigated the value businesses and consumers place on travel time and travel time-savings, based on economic costs and willingness to pay for faster travel options. Below are some factors affecting travel time cost values (VTPI, 2003):

- Travel time costs incorporate various qualitative attributes of travel, such as comfort, safety, security and prestige.
- Personal travel time is usually estimated at ¼ to ½ of prevailing wage rates.
- Per-minute time costs tend to increase for longer commuting trips (more than about 20 minutes).
- Travel time costs tend to be higher for driving under congested conditions, and for passengers under uncomfortable conditions.
- Travel time costs tend to be particularly high for unexpected delays.
- Some travel time has a low cost or positive value because people enjoy the experience, for example, for a pleasant drive or recreational train trips.
- Under pleasant conditions, walking and cycling can have positive value, but under unpleasant or unsafe conditions (for example, walking along a busy highway or waiting for a bus in an area that seems dirty and unsafe), time spent walking, cycling and waiting for transit has costs two or three times higher than time spent travelling.

- Travel time costs tend to increase with income, and tend to be lower for children and people who are retired or unemployed (or, put differently, people with full-time jobs tend to have more demands on their time, and so tend to be willing to pay more for travel time savings.)
- Preferences vary. Some people place a higher cost on time spent driving and a low cost on time spent as a transit passenger, while others have the opposite preferences.

Recommended values for travel time in USA

The USA recommendations for the values of travel time are based on research not only in the USA but also in Europe and elsewhere. The rationale behind the recommendations can be applied universally and even some of the values can be applied fairly straightforwardly since there are nearly no difference between U.S. dollar and euro and the used hourly average wage rate of $12.00 is fairly close to the average wage rate in many European countries (although at the time of writing, the recent depreciation of the Dollar has reduced its value relatively to the Euro).

The U.S. Department of Transport (DOT) uses following overall travel time values for evaluating transportation projects (in 1997 1USD = 0.9 euro)[2]: $12.00 as average wage rate, $8.90/person-hour for the in-vehicle time and $17.00/person-hour for the out-of-vehicle time (e.g. waiting for a bus). The recommended overall value for the in-vehicle time is 74% of the wage rate and the out-of-vehicle time is valued 1.9 times the in-vehicle time. The recommended values for travel time savings based on wage rates for local and intercity travel and separately for personal and business trips are presented in Table 3.7.

Table 3.7 Recommended values for travel time savings by U.S.DOT (Percent of wage rates)

	Surface modes	Air travel
Local travel *)		
Personal	50% (35-60%)	
Business	100% (80-120%)	
Intercity travel *)		
Personal	70% (60-90%)	70% (60-90%)
Business	100% (80-120%)	100% (80-120%)

*) Applies to all in-vehicle time. Walk access and waiting time should be valued at 100% of wage rates. Values in parentheses indicate plausible ranges for use in sensitivity analysis.
Source: VTPI 2003

There are also recommendations for values for different passenger categories. An example from Canada is shown in Table 3.8.

[2] At the time of writing (February 2004) the 1USD=0.8 euro)

Table 3.8 Travel time values recommended by British Columbia Ministry of Transportation and Highways, 1992)

Passenger category	**Travel time value** [1)]
Personal vehicle driver	50% of current average wage
Adult car or bus passenger	35% of current average wage
Child passenger under 16 years	25% of current average wage
Commercial vehicle driver	Wage rate plus fringe benefits

[1)] Congestion increases travel time costs for drivers according to the Level of Service (LOS) ratings i.e. levels of congestion: LOS D: factor 1.33, LOS E: factor 1.67 and LOS F: factor 2.0.
Source: VTPI 2003

Values for aviation passenger travel time valuation recommended by the Federal Aviation Administration[3] are derived from the wage rates as well. The value for personal travel recommended is 70% of the weighted average of annual income categories in the survey for "visiting friends," "sightseeing," and "other" travel purposes divided by an assumed 2000 hours of work per year. The value for "business" travel is 100% correspondingly. The fractions of 70% (range 60-85%) and 100% (range 80-120%) were recommended by a panel of transportation economists. The range of values is based on variation in panel member opinions. (See Appendix 1.3 for actual figures.)

3.6.4 Summary of value of time recommendations

Comparing the UNITE values with the US recommendations we notice that the values of 4€/h and 6€/h correspond to percentages for personal travel of 35% and 50% of an hourly wage rate around 11-12€ (around 21 000 – 23 000 €/year). In addition, findings from the UNITE-project refer to 50% of the average wage rate as the overall value of in-vehicle time in urban transport.

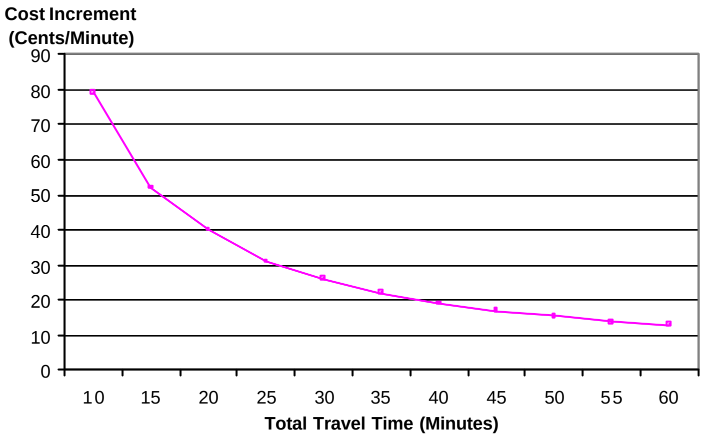
In Europe, where the employer's contributions are fairly high, it is recommended to use 100% employer payment (100% of wage rate plus employer's contribution) for business trips instead of 100% of employee's wage rate. Assuming that the employer's contribution is around 50% of the wage rate, the UNITE values correspond to wages 14€/h and 18€/h for land and air travel respectively. Given that people who travel in business have on average a higher salary and those who fly for business even higher, all the recommendations fit together. For inter-urban personal ground travel, the US recommendations are somewhat higher than the UNITE values that only correspond to 35-65% of the average wage rate.

3.6.5 Effects of congested and unreliable travel conditions

Travel time costs tend to be significantly higher under congested and unpredictable travel conditions. As evaluation of congestion is discussed in more detail in Chapter 7, here we discuss only valuation related directly to the value of in-vehicle time.

[3] "Economic Values for Evaluation of Federal Aviation Administration Investment and Regulatory Programs", FAA, 1998.

The note of Table 3.8 above suggests factors up to 2.0 for badly congested situations. The UNITE-project suggests an average, overall factor of 1.5 for congestion (UNITE D7, 2003). Figure 3.2 shows willingness to pay for reduced congestion delay for various trip lengths. It can be seen that according to this study (Small et al., 1999) the decrease of the cost increment per minute is inversely proportional to the increase of the uncongested travel time i.e. trip length.



Source: Small et al (1999)

Figure 3.2 Cost of shifting from uncongested to congested travel

The so-called reliability ratio is based on the standard deviation of trip time. It is a measure of the reliability of the estimated or time-tabled travel time. The reliability ratio of 1.0 in the PETS-project (see the last row with the PETS results in Table 3.6) means that one minute of standard deviation of travel time is valued at 1.0 times normal IVT travel time.

Bruzelius (2002) discusses the different elements of congested traffic conditions that need to be considered and summarises previous research results. He reports a variation from 0.7 to 2.2 for the reliability ratio.

According to the Victoria Transport Policy Institute Handbook (VTPI 2003) willingness to pay for more reliable arrival time is based both on the average travel time and the standard deviation of travel time. It means that if on a certain route there is substantial variation in the travel time such that the standard deviation is high, people are willing to pay more per minute of increased reliability than on another route of the same length but with less variation in travel time. The amount people are willing to pay depends also on income and trip purpose.[4]

Various studies suggest that travel time costs under congested conditions should be calculated at 1.3 - 2.5 times that of overall travel time savings. Figure 3.2 supports this

[4] According to U.S studies studies (VTPI 2003) people with higher income (over $45 000/year, appr. 40 000€/year) are willing to pay $0.26 (appr. 0.23€) per minute of standard deviation of travel time on work trips and on non-work trips $0.21 (appr. 0.19€). People with lower income (under $40 000/year) are willing to pay 20% less.

as an average and suggest that for shorter trips the factor should be even higher and for longer somewhat less.

3.6.6 Kilometre based values of time

In practice, it is sometimes easier to use only trip length based calculations also for travel time components of the generalised cost. Especially in connection with certain types of transport models this is more convenient. Conversion of values of time to values per kilometre involves knowledge or usually assumptions about the average speeds by mode and location, congestion etc. Instead of using average values for a whole day it is recommended to separate at least peak and off-peak periods of day. In addition, values of time according to purpose and traveller group (distributions by mode, purpose and traveller group, if available), car occupancy figures etc. should be used separately for each time period. Appendix 1.6 gives an example of such a calculation.

3.7 Evaluation of other cost components

Most of the other components of the generalised cost for a passenger, both variable and fixed costs are more dependent on the specific circumstances of the case study and are based on the actual local costs such as costs of having a car, taxes, insurance, fuel, parking policy and public transport fares. Therefore it is recommended to assess these costs using present local values and for the growth rate either national estimates or for instance the EU15 GDP growth rate (approximately 2.0-2.5% per annum).

For the car mode variable costs such as fuel price, parking charges, taxes, tolls, congestion charging, and such maintenance and insurance costs that depend on the amount of travel must be taken into account. According to previous EU research (e.g. FATIMA and PROSPECTS) and national kilometre allowances used in EU countries average car cost per kilometre is 20-30 cent/km of which fuel costs correspond to nearly one third and non-fuel costs around two thirds. Taxes for *fuel costs* range from 65% to 80% for unleaded petrol, and from 60% to 72% for diesel in the different European countries. If policy instruments examined in the SPECTRUM case study have no effects on car ownership, only a small proportion of the fixed costs should be taken into account (transport models commonly use 10-50% of the non-fuel cost). On the other hand if the policy instruments examined affect car ownership, the full cost of the car must be considered. Some previous case study examples are presented in Appendix 1.5.

Some variable costs, *parking charges* for example, may have different values according to time of day and week or by trip purpose. Since charges for long-term parking differ from short-term parking, commuting trips may be given different parking charges than other purposes that generally require a shorter duration at the destination.

3.8 Conclusions and recommendations

It is evident that the monetary values of time vary according to user group, not least because of variations in income and other social characteristics. There is also evidence that the value of in-vehicle time varies according to mode, but not necessary because of the mode itself but rather due to variation in comfort, quality, security, reliability and other auxiliary attributes of the mode and journey. Unlike in-vehicle time, walk, wait and headway values are not expected to vary according to mode. Nonetheless, they are expected to vary across user groups and thus are often expressed in relation to the in-vehicle time.

The values of time presented in this chapter seem to have substantial variation. However, this is partly misleading and the different values still have a common basis. If we look at various studies of different valuations of time by transport mode we have to bear in mind that this embeds both the differences in person groups (age, activity, income, gender etc,) and travel purpose groups of passengers using the mode. On the other hand, if we in a specific study situation originally have travel time values by purpose and the modal split share for all these person groups, by summing up we would end up with the same average values of time for each mode. When evaluating the effects of transport policies we look at the changes in modal split share as persons shift from one mode to another, not the overall time valuation of the transport system. Thus for the specific people groups changing mode, in most cases mode independent values of time should be used.

There has been significant discussion about whether small increments of time should be valued at lower rates than larger increments. Arguments for valuing smaller increments of time less than larger ones emphasize the difficulties of making effective use of smaller increments, particularly when unanticipated. The present state of theoretical and empirical knowledge does not appear to support valuing small increments of time less than larger ones.

For the SPECTRUM case studies where the intention is to evaluate the effects of different transport instrument packages we recommend the UNITE/MC-ICAM approach of using the same values of time for different modes but differentiating for user groups (people working, retired, children etc.), travel purpose (business, commuting, leisure, etc.) and for urban/inter-urban travel context. This is also in line with the U.S. recommendations and practical recommendations of many European studies (Wardman, 2001, Mackie et al. 2001 and Bruzelius 2002). Based on these rules of thumb of in-vehicle time values for different travel purposes and context can be given:

- Business: 100% of wage rate plus employer's contribution (100% employer payment)
- Urban commuter: around 50% of wage rate
- Urban other private: 30-40% of wage rate (commuting trips should be valued around 15-25% higher than other private trips)
- Inter-urban commuter: 50-80% of wage rate
- Inter-urban other private: 35-45% of wage rate.

In addition, a person's valuation of travel time incorporates various qualitative attributes of travel, such as comfort, congestion, safety, security, reliability and prestige which should also be taken into account if possible.

The value of in-vehicle time increases with distance, with a larger increase for the car mode. Walk and wait time values do not increase as strongly with distance whilst headway becomes less important as distance increases.

All studies show that other components of travel time related to a mode, such as auxiliary travel, wait and transfer times, are valued more highly than the in-vehicle time, around 1.5-2.5 times as valuable as the in-vehicle time. (UNITE/MC-ICAM: factor 1.5 for delay and congestion and factor 1.6 for auxiliary time, wait and transfer). In general, the value of wait time appears to be larger than the value of walk time. Variations in the values seem to relate to the supply factors, e.g. comfort of transfer, surroundings for waiting and information provision. Therefore, if local studies of valuation are available, these values should be used (the values of walk time and particularly wait time are higher when obtained from revealed preference data than stated preference studies).

Travel times in congested situation (peak hour, bottlenecks) should be valued around 1.5 times that of uncongested travel time for private trips and 1.1-1.2 times for business trips. The low value for the business trips relates to the "full payment" of the total time spent in travelling.

For long time planning time values for business trips should follow the expected real wages. The time values for private trips have been estimated to follow the GDP per capita with an elasticity of 0.5-0.75 (see UNITE, 2003 and Bruzelius, 2002).

In practice, it is sometimes more convenient to use distance based values in the evaluation procedure. Based on given values of time components it is possible to convert these to average kilometre base values by using average speeds for each mode and traffic situation concerned as is shown in the example in Appendix 1.6.

The variable costs for the user are entirely location and study specific and the fixed costs usually country specific.

4 Impacts on freight

4.1 Introduction

In this chapter, we analyze the measurement of impacts on freight transport, classified both by different branches of industry and by spatial dimension. The benefits of freight transport improvements may be large. An understanding of the broad market forms and behavioural responses to policies in these are established in broad terms. Therefore, a framework is provided to analyze the effects of policy measures on freight transport.

In Section 4.2, an overview of four methods to be used in the case studies is given. First, a general model with respect to freight transport is presented in Section 4.2.1. In this way, it is possible to determine crucial elements in the determination of the impact of policy measures on freight transport. In Section 4.2.2 the relation between demand for freight transport and economic activity is described. A partial equilibrium model is worked out in Section 4.2.3. This gives a framework for the demand for and supply of freight transport by mode, as well as the equilibrium conditions. Section 4.2.4 focuses on indirect effects in and outside the freight sector. In a final section, the most important conclusions are reported and recommendations are given for the case studies.

4.2 Alternative modelling approaches

4.2.1 A general model

In its most simplified and generalised form, the market for freight transport can be represented by the demand for and supply of freight transport on the existing network. The network, in combination with the fleet size, are the major determinants of the available capacity.

The demand for transport, D, is a derived demand and is determined mainly by the economic activity (indicated by Y), the geographical localisation or spread of production (e.g. indicator of number of labour intensive industries per region) and consumption activities (e.g. indicator of population per region), RS, and the price of transport, P[5]. The supply, S, depends upon the price, P, the generalised cost, C, and regulatory policies, RP.

The upper bound of freight transport supply in the short run is determined by the available capacity for freight transport, CAP. The rate of capacity utilisation will have an impact on the time cost, as is the case when there is congestion.

Summarising we have:

$$D = f(Y, RS, P) \qquad (1)$$

[5] The price of transport refers to the out-of-pocket cost, which has to be paid by the firm that demands freight transport on the one side and is asked by the firm who supplies freight transport.

$$\text{with } \frac{\partial D}{\partial Y} \geq 0, \quad \frac{\partial D}{\partial RS} \geq 0, \quad \frac{\partial D}{\partial P} \leq 0,$$

$$S = \min\{f(P, C, RP), CAP\} \qquad (2)$$

$$\text{with } \frac{\partial S}{\partial P} \geq 0, \quad \frac{\partial S}{\partial C} \leq 0$$

It is assumed that Y, RS, C, RP and CAP are exogenous. The generalised cost C[6] will depend upon labour costs, the user cost of capital and the time cost. The last one will be affected by the utilisation of the existing capacity. It will increase, for instance, when there is congestion. In this way the existing capacity enters the supply function.

Assuming perfect competition, the price P and the amount of freight transport Q are determined by the equilibrium condition:

$$Q = D = \text{Min}\{S, CAP\} \qquad (3)$$

Figure 4.1a illustrates the equilibrium price and quantity when the capacity is not fully utilised. The supply function (MC, marginal cost) is nonlinear indicating the impact of the rate of capacity utilisation on the generalised cost. The closer the production of transport comes to the available capacity, the higher the probability of congestion and the higher the generalised cost. Figure 4.1b gives the equilibrium when the capacity is fully utilised. Figure 4.1a can be an off-peak situation and Figure 4.1b a situation with congestion in a peak period.

Figure 4.1a

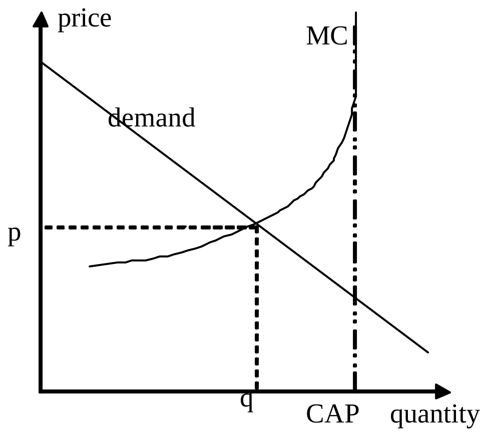


Figure 4.1b

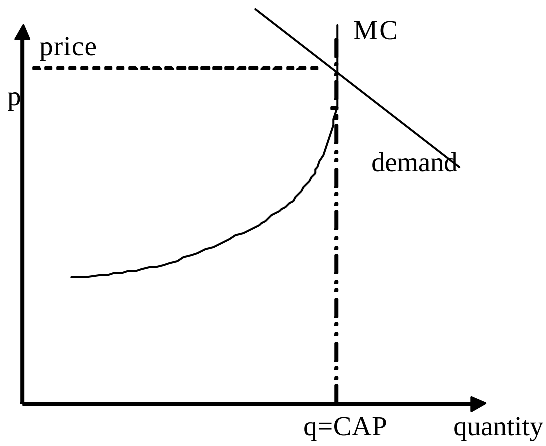


Figure 4.1 Equilibrium price and quantity

Interaction between freight transport and passenger transport in this simple model is by means of the rate of capacity utilisation. If the rate of capacity utilisation of

[6] The generalised cost refers to costs that have to be made by the firm who supplies freight transport in order to be able to supply transport (e.g. labour costs, user cost of capital and the time cost).

passenger transport increases at a higher rate than freight transport, the capacity available for freight transport will decrease.

This model can be used to illustrate in a rather general way the impact of a number of policy measures.

Internalising the external costs, for instance by means of a tax, increases the cost for the producer, which will result in a lower level of freight transport at a higher price. The exact magnitude of the price increase and the transport reduction will depend upon the tax level and the price elasticities of both supply and demand as illustrated in Figure 4.2 (with MSC, marginal social cost).

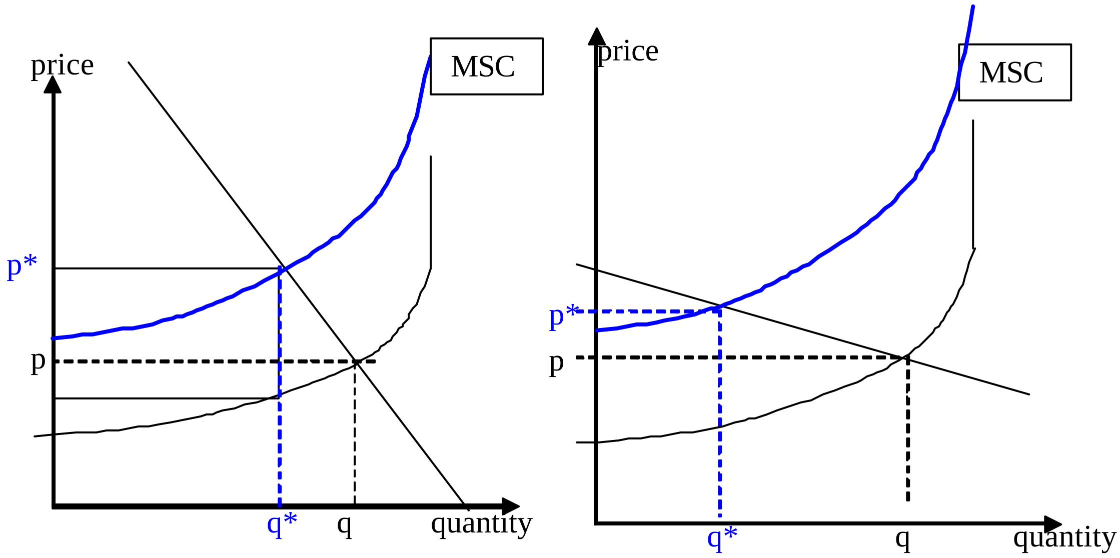


Figure 4.2 Internalising external costs for an inelastic and elastic demand function

Most companies demanding freight transport will try to incorporate the higher price they have to pay for transport into the price of the commodities. When the transport cost is only a small part of the final price of the commodity, changes in the transport price will hardly affect the demand for the commodities, and hence, the demand for transporting those commodities. Therefore the demand for freight transport of this type of commodities is rather inelastic. Only for commodities for which the transport cost is a large component of their price, the demand for shipping those commodities will be less inelastic.

From this general analysis it becomes clear that a number of elements are crucial in the determination of the impact of policy measures on freight transport: the determination of the marginal costs, the demand for transport, the price elasticity of demand and supply in the transport sector, the capacity and the type of commodities.

4.2.2 The relation between the demand for freight transport and economic activity

The demand for freight transport is a derived demand and is largely determined by economic activities such as production and trade. In an age of globalisation this relationship becomes even more important. The impact of increasing economic growth and international trade of freight transport has changed over time and differs over countries.

Using annual data from 1991-2000 for fifteen European countries Table 4.1 gives the estimates for the short run elasticities of freight transport with respect to gross domestic product, based on the following model:

$$\frac{dFT_{it}}{FT_{it}} = b\,\frac{dGDP_{it}}{GDP_{it}} + u_{it} \qquad (4)$$

with
FT_{it} freight transport in country i in year *t*
GDPit gross domestic product of country i in year *t*
u_{it} stochastic error term.

Table 4.1 Short run elasticities of freight transport with respect to gross domestic product (1991-2000)

Country	Elasticity estimate	Country	Elasticity estimate
Belgium	1.398	Italy	0.804
Denmark	1.467	Luxembourg	1.215
Germany	1.097	The Netherlands	0.814
Greece	1.412	Austria	0.750
Spain	1.324	Portugal	0.474
France	0.649	Finland	2.163
Ireland	0.851	Sweden	0.512
		UK	1.015

Source: Meersman, H. & E. Van de Voorde (2003), Decoupling of freight transport and economic activity: Realism or utopia?, paper presented at the OECD-ECMT conference, Budapest, 29-31 October 2003.

This illustrates clearly the close relationship between economic growth and freight transport demand. As a consequence, reducing freight transport will be a very difficult, nearly impossible job (if this is a policy objective). Therefore, one should try to shift part of road haulage to other modes, improve the use of the existing capacity and increase, if necessary, the capacity.

4.2.3 A partial equilibrium model for freight transport by different modes

As the largest part of freight transport is by road, one of the targets for sustainable freight transport growth is to induce shifts from road to other modes of transport. In order to be able to track the impacts of policy measures on the mode choice decisions made in the freight transport sector, a more detailed model is needed.

It is assumed that in the short run the transportation infrastructure and part of the superstructure such as terminals, is given.

The demand for freight transport by mode *i*

The demand for freight transport by mode *i* consists of the demand of households (private consumers e.g. shopping), the demand of the government and the demand of firms. As in general, households transport themselves the commodities they buy, we will not introduce this part of freight demand in the model. Also the demand of the government is neglected in this model. This implies that the demand for freight transport comes mainly from private companies out of the production, wholesale and retail sector.

The demand for transport by a mode is the result of the decision of the companies to minimise the cost for the production of a given amount of commodities (*j* stands for all other modes):

$$\text{Min } wL + cK + p_iD_i + p_jD_j + npc_i + npc_j \qquad (5)$$

subject to the production function

$$Y = f(K, L, D_i, D_j)$$

with

Y	production
w	unit labour cost
L	labour
c	unit user cost of capital
K	capital stock
D_i, D_j	transport by mode *i* and/or mode *j* j
p_i, p_j	price of transport by mode *i* and mode *j*
npc_i, npc_j	non-price costs of mode *i* and *j* (costs related to time, reliability, etc.)[7]

When it is assumed that the production function is separable, the demand for mode *i*, D_i, is determined by the economic activity of the companies, the price they have to pay for transport by the mode under consideration and the price of alternative modes, non-price characteristics of the modes such as flexibility, speed, reliability, etc.:

$$\mathbf{D_i} = f(Y, p_i, p_j, np_i, np_j) \qquad (6)$$

Supply of freight transport by mode *i*

The supply of freight transport by mode *i* comes from public and private transportation companies (national and international). As the public sector is mainly involved in large scale infrastructure investment, we will focus on the private sector. Private transportation companies want to maximise their profits:

$$\max \; p_i S_i - w\,LT_i - c\;KT_i - oc_i S_i \qquad (7)$$

subject to $S_i = (f(LT_i, KT_i, tec_i), CAP_i)$

with

[7] Non-price costs refers to monetised costs, for example the value of time

w	unit labour cost
LT_i	labour in transport mode *i*
c	unit user cost of capital
KT_i	capital stock in transport mode *i*
S_i	supply of transport by mode *i*
p_i	price of transport by mode *i*
oc_i	other costs of mode *i* (costs related to time, reliability,...)
tec_i	technology used
CAP_i	transport when the capacity is fully utilised. As in the general case the available capacity can put an upper limit on the supply of transport.

For a given capital stock and technology, this results in the supply of transport:

$$\mathbf{S_i} = \text{Min}(\, f(p_i, oc_i, w, c, K_i, tec_i)\,,\, CAP_i) \qquad (8)$$

Equilibrium conditions for the different modes

In equilibrium and assuming perfect competition, the price of the mode *i* and the quantities transported by mode *i* will be determined by:

$$\mathbf{Q_i = D_i = Min(S_i, CAP_i)} \qquad (9)$$

resulting in

$$Q_i = q_i(Y, p_j, np_i, np_j, oc_i, w, c, K_i, tec_i, CAP_i) \qquad (10)$$

$$p_i = p_i(Y, p_j, np_i, np_j, oc_i, w, c, K_i, tec_i, CAP_i) \qquad (11)$$

When there is no capacity constraint and when the other modes are considered to be exogenous to the model, one can trace the impacts of changes in the exogenous variables, starting from the total differentials:

$$\begin{cases} \boldsymbol{d}\mathbf{D_i} = df(Y, p_i, p_j, np_i, np_j) \\ \boldsymbol{d}\mathbf{S_i} = df(p_i, oc_i, w, c, K_i, tec_i) \\ \boldsymbol{d}\mathbf{Q_i = dD_i = dS_i} \end{cases} \qquad (12)$$

or (13)

$$\begin{cases} dQ_i = \dfrac{\partial D_i}{\partial p_i} dp_i + \dfrac{\partial D_i}{\partial Y} dY + \dfrac{\partial D_i}{\partial p_j} dp_j + \dfrac{\partial D_i}{\partial np_i} dnp_i + \dfrac{\partial D_i}{\partial np_j} dnp_j \\ dQ_i = \dfrac{\partial S_i}{\partial p_i} dp_i + \dfrac{\partial S_i}{\partial oc_i} doc_i + \dfrac{\partial S_i}{\partial w} dw + \dfrac{\partial S_i}{\partial c} dc + \dfrac{\partial S_i}{\partial K_i} dK_i + \dfrac{\partial S_i}{\partial tec_i} dtec_i \end{cases}$$

which give (14)

$$\begin{cases} dQ_i = \dfrac{\left[\begin{array}{l}\dfrac{\partial S_i}{\partial p_i}\left(\dfrac{\partial D_i}{\partial Y}dY + \dfrac{\partial D_i}{\partial p_j}dp_j + \dfrac{\partial D_i}{\partial np_i}dnp_i + \dfrac{\partial D_i}{\partial np_j}dnp_j\right) - \dfrac{\partial D_i}{\partial p_i}\left(\dfrac{\partial S_i}{\partial oc_i}doc_i + \dfrac{\partial S_i}{\partial w}dw + \dfrac{\partial S_i}{\partial c}dc\right. \\ \left. + \dfrac{\partial S_i}{\partial K_i}dK_i + \dfrac{\partial S_i}{\partial tec_i}dtec_i\right)\end{array}\right]}{\dfrac{\partial S_i}{\partial p_i} - \dfrac{\partial D_i}{\partial p_i}} \\ \\ dp_i = \dfrac{\dfrac{\partial D_i}{\partial Y}dY + \dfrac{\partial D_i}{\partial p_j}dp_j + \dfrac{\partial D_i}{\partial np_i}dnp_i + \dfrac{\partial D_i}{\partial np_j}dnp_j - \left(\dfrac{\partial S_i}{\partial oc_i}doc_i + \dfrac{\partial S_i}{\partial w}dw + \dfrac{\partial S_i}{\partial c}dc + \dfrac{\partial S_i}{\partial K_i}dK_i + \dfrac{\partial S_i}{\partial tec_i}dtec_i\right)}{\dfrac{\partial S_i}{\partial p_i} - \dfrac{\partial D_i}{\partial p_i}} \end{cases}$$

When there is a capacity constraint one has (15)

$$\begin{cases} dQ_i = \dfrac{\partial D_i}{\partial p_i}dp_i + \dfrac{\partial D_i}{\partial Y}dY + \dfrac{\partial D_i}{\partial p_j}dp_j + \dfrac{\partial D_i}{\partial np_i}dnp_i + \dfrac{\partial D_i}{\partial np_j}dnp_j \\ dQ_i = dCAP_i \end{cases}$$

or (16)

$$\begin{cases} dQ_i = dCAP_i \\ dp_i = \dfrac{dCAP_i - \left(\dfrac{\partial D_i}{\partial Y}dY + \dfrac{\partial D_i}{\partial p_j}dp_j + \dfrac{\partial D_i}{\partial np_i}dnp_i + \dfrac{\partial D_i}{\partial np_j}dnp_j\right)}{\dfrac{\partial D_i}{\partial p_i}} \end{cases}$$

One can now calculate, for instance, the impact of an increase of the price of mode *j* on the quantity of mode *i*.

When there is no capacity constraint, this gives

$$\frac{dQ_i}{dp_j} = \frac{\dfrac{\partial S_i}{\partial p_i}\dfrac{\partial D_i}{\partial p_j}}{\dfrac{\partial S_i}{\partial p_i} - \dfrac{\partial D_i}{\partial p_i}} \qquad (17)$$

or in terms of elasticities, this becomes

$$\frac{dQ_i / Q_i}{dp_j / p_j} = \frac{e^{S_i}_{p_i} e^{D_i}_{p_j}}{e^{S_i}_{p_i} - e^{D_i}_{p_i}} \qquad (18)$$

It is clear that in order to calculate the impact of policy measures on the quantity and price of a mode, one has to know the elasticity of the demand and supply functions of the mode with respect to the variables that are relevant for the policy measures.

The story becomes even more complicated if one considers all the modes as endogenous. In a two-mode case, one gets the general equilibrium (19):

$$\begin{cases} Q_i = q_i(Y, np_i, np_j, oc_i, oc_j, w, c, K_i, K_j, tec_i, tec_j, CAP_i, CAP_j) \\ p_i = p_i(Y, np_i, np_j, oc_i, oc_j, w, c, K_i, K_j, tec_i, tec_j, CAP_i, CAP_j) \\ Q_j = q_j(Y, np_i, np_j, oc_i, oc_j, w, c, K_i, K_j, tec_i, tec_j, CAP_i, CAP_j) \\ p_j = p_j(Y, np_i, np_j, oc_i, oc_j, w, c, K_i, K_j, tec_i, tec_j, CAP_i, CAP_j) \end{cases}$$

and the impact of policy measures when there is no capacity constraints can be calculated using the following total differentials:

$$\begin{cases} \mathbf{dD_i} = df(Y, p_i, p_j, np_i, np_j) \\ \mathbf{dS_i} = df(p_i, oc_i, w, c, K_i, tec_i) \\ \mathbf{dQ_i = dD_i = dS_i} \\ \mathbf{dD_j} = df(Y, p_i, p_j, np_i, np_j) \\ \mathbf{dS_j} = df(p_j, oc_j, w, c, K_j, tec_j) \\ \mathbf{dQ_j = dD_j = dS_j} \end{cases} \qquad (20)$$

A number of impacts can be studied with those models, but they all require the knowledge of the demand and supply elasticities. The problem is that it is not at all evident that the elasticities are constant over time, that they are the same for different countries and regions and for different commodity groups. There is also a difference between the effect of price increases and decreases. Even a distinction between minor and major price changes should be made. Furthermore, short-time elasticities as well as long-time elasticities have to be considered. So far, there is little empirical information on those elasticities in the literature.

Based on a literature review, we illustrate the spread in reported elasticities. First of all, we mention two well quoted papers in the literature: Oum, Waters II and Yong (1990, 1992) and Abdelwahab (1998). The other elasticities are selected on the basis of two criteria:

- the published elasticities should be reported in a paper after 1992 (this is done because in 1992 a standard overview paper of Oum has been published);
- the published elasticities are based on observations in the countries of the European Union, new member states of the European Union or candidate members of the European Union.

It should be noted that in the literature it is not always clear that the mentioned elasticities are derived elasticities or assumed elasticities. In the overview, we present derived elasticities as far as we can distinguish them.

Table 4.2 shows the spread in reported elasticities. Using different functional forms results in different elasticities (Oum et al (1990, 1992)). Reported elasticities are based on estimations for the United States, Canada, the United Kingdom, Australia, New Zealand, Europe (excluding the United Kingdom), Brazil, India, Pakistan and some multicountry studies and studies with unknown data sources.

Abdelwahab (1998) reports own-price and cross-price elasticities[8] in the intercity freight transport market. Across commodity groups and geographic territories, significant differences were noticed. The truck price elasticity of demand ranged between -0.749 and -2.525; the rail price elasticity of demand ranged between -0.956 and -2.489; the rail-truck cross-price elasticity of demand ranged between 0.904 and 2.532. Data was drawn form the US Commodity Transportation Survey.

Table 4.2 Own-price elasticities of demand for freight transport
(Note: All elasticity figures are negative, figures in parentheses are mode choice elasticities)

Mode	Range Surveyed	Most Likely Range	No. of Studies
Rail:			
Aggregate Commodities	0.60-1.52 (0.09-1.79)	0.40-1.20	4
Assembled Automobiles	0.65-1.08	0.70-1.10	2
Chemicals	0.39-2.25 (0.66)	0.40-0.70	3
Coal	0.02-1.04	0.10-0.40	2
Corn, Wheat etc.	0.52-1.18	0.50-1.20	3
Fertilizers	0.02-1.04	0.10-1.00	1
Foods	0.02-2.58 (1.36)	0.030-1.00	9
Lumber, Pulp, Paper etc.	0.05-1.97 (0.76-0.87)	0.10-0.70	7
Machinery	0.61-3.55[a]	0.60-2.30	3
Paper, Plastic and Rubber Products	0.17-1.85	0.20-1.00	4
Primary Metals and Metallic Products	0.02-2.54[a] (1.57)	1.00-2.20	5
Refined Petroleum Products	0.53-0.99	0.50-1.00	3
Stone, Clay and Glass Products	0.82-1.62 (0.69)	0.80-1.70	4
Truck:			
Aggregate Commodities	0.05-1.34	0.70-1.10	1
Assembled Automobiles	0.52-0.67	0.50-0.70	1
Chemicals	0.98-2.31	1.00-1.90	2
Corn, Wheat, etc	0.73-0.99	0.70-1.00	2
Foods	0.32-1.54	0.50-1.30	3
Lumber, Wood, etc.	0.14-1.55	0.10-0.60	3
Machinery	0.04-1.23	0.10-1.20	3

[8] A price elasticity of demand measures the responsiveness of demand to a change in price. However, in the literature it is not always clear what the exact content of the price is (out of pocket costs, generalised costs, non-price costs...). For a description of concepts of elasticities, see Oum (1992). An elasticity is a measure of the sensitivity of one variable to another. Specifically, it is a number that tells us the percentage change that will occur in one variable in response to a 1 percent change in another variable. An own-price elasticity (direct price elasticity) of demand refers to the percentage change in the quantity demanded for a good that results from a 1 percent increase in its own price. A cross-price elasticity of demand refers to the percentage change in the quantity demanded for a good that results from a 1 percent increase in the price of another good. (Pindyck & Rubinfeld, 1995).

Primary Metals and Metallic Products	0.18-1.36	0.30-1.10	3
Paper, Plastic and Rubber Products	1.05-2.97	1.10-3.00	2
Refined Petroleum Products	0.52-0.66	0.50-0.70	3
Stone, Clay and Glass Products	1.03-2.17 [a]	1.00-2.20	2
Textiles	0.43-0.77	0.40-0.80	1
Air:			
Aggregate Commodities	0.82-1.60	0.80-1.60	3
Shipping: Inland Waterway [b]			
Aggregate Commodities	(0.74-0.75)	-	1
Chemicals	0.75	-	1
Coal	0.28	-	1
Crude Petroleum	1.49	-	1
Grain	0.64-1.62	0.60-1.60	2
Lumber and Wood	0.60	-	1
Non-Metallic Ores	0.55	-	1
Primary Metal	0.28	-	1
Pulp and Paper	1.12	-	1
Stone, Clay and Glass Products	1.22	-	1
Shipping: Ocean [b]			
Dry Bulk Shipment [c]	0.06-0.25	-	1
Foods	0.20-0.31	-	1
Liquid Bulk Shipment	0.21	-	1
General Cargo	0.00-1.10	-	1

[a] The high elasticity estimates may reflect a low market share of aggregate freight of the mode when using the translog cost function in estimation.
[b] There have been very few empirical studies on shipping, hence the elasticity estimates reported here should be interpreted with caution.
[C] These include coal, grain, iron ore and concentrates, etc.
Source: Oum et al (1990)

Beuthe et al. (2001) present direct (own-price) and cross-price elasticity estimates of the demands for three freight transportation modes: rail, road and inland waterways (Table 4.3). They are computed for 10 different categories of goods with a detailed multimodal network model of Belgian freight transports. The estimates are compared with previously published estimates, and, in particular, with Abdelwahab's results. The measured elasticities (indirectly derived from observed data) appear to be of the same order of magnitude as price-elasticities estimated by more classical statistical methods (directly derived from observed modal choices on the basis of econometric models).

Table 4.3 Aggregate elasticities when costs are reduced by 5%
(short distance: <300 km; long distance: > 300 km)

		Total cost reduction*)			Travel costs reduction			Total cost variation*)					
								Short distances			Long distances		
		Road	Rail	Water	Road	Rail	Water	Road	Rail	Water	Road	Rail	Water
Tons	Road	-0.59	0.09	0.11	-0.48	0.04	0.04	-0.57	0.08	0.12	-0.64	0.12	0.09
	Rail	2.19	-1.77	1.75	1.95	-1.25	1.50	2.24	-2.96	1.32	2.10	-1.58	0.96
	Water	3.59	0.47	-2.13	2.81	0.32	-1.44	5.29	1.09	-1.85	1.03	0.32	-1.33
T/km	Road	-1.21	0.45	0.09	-1.10	0.42	0.06	-1.03	0.12	0.13	-1.30	0.69	0.07
	Rail	2.03	-1.25	0.94	1.94	-1.14	0.88	2.91	-2.88	1.35	1.90	-1.21	0.66
	Water	1.75	0.33	-1.72	1.43	0.25	-1.53	4.42	1.01	-1.39	0.84	0.29	-1.37

*) The total cost concept is based on Beuthe et al (2001) and includes costs for the vehicle operations, the handling costs and the commodities inventory costs. An analysis can be found in Jourquin (1995). Travel costs refer to the costs of the vehicle operations.
Source: Beuthe et al (2001)

On the basis of a literature study, a survey of consignors and model simulations, CEDELFT (1999) concludes that Dutch demand for road freight services is fairly sensitive to price changes, a 1% price rise (per tonne-kilometre) leading to an estimated 0.6-0.9% reduction in transport volume (in tonne-km).

According to CEDELFT (2001), literature on the price of air freight transport and marine shipping is too scarce for quantitative conclusions to be drawn.

The price elasticity of freight transport (measured in tonne-miles) in Denmark is calculated to be -0.47, while the elasticity of freight traffic (measured in truck-kilometers) is -0.81 (VTPI (2003) and Bjørner (1999)).

Meersman and Van de Voorde (1997) report own-price elasticities for road, rail and inland navigation (Belgium) (Table 4.4 and Table 4.5).

Table 4.4 Own-price elasticities for road, rail and inland navigation in Belgium (specified on OD-relations with 3 modes)

	Aggregate	Metal products	Chemicals
Road	-0.1449	-0.6282	-0.0412
Rail	-2.653	-1.5400	-2.9476
Inland navigation	-1.191	-4.0475	-1.0635

Source: Meersman and Van de Voorde (1997)

Table 4.5 Own-price elasticities for road and inland navigation in Belgium (specified on OD-relations with 2 modes: road-inland navigation)

	Agricultural products	Metal products	Chemicals
Road	-0.0565	-0.2259	-0.0729
Inland navigation	-0.6384	-1.2821	-0.3868

Source: Meersman and Van de Voorde (1997)

TRL (2001b) reports direct price (own-price) elasticities for road freight transport and cross price elasticities for rail freight transport with respect to price changes in road transport for Germany (based on "Impact analysis for the Planned German Motorway Toll (SVA)). A distinction is made between minor price changes in road transport and major price changes, where small price changes include all price increases up to 20% against the reference case. Other elasticities are reported in the text, but the authors explicitly state that "care must be taken when translating the German experiences to international transport markets".

Table 4.6 Overall demand price elasticities of road freight transport in Germany

	Direct price elasticity	Cross price elasticity
Small price changes (dProad<20%)	-0.08	0.21
Big price changes (dProad>=20%)	-0.16	0.46

Source: TRL (2001b)

4.2.4 Interactions in freight transport

In order to trace the full impact of policy measures aimed at the freight transport sector one should not only consider the direct effects within the sector, but also the indirect effects in and outside the sector. This is only possible if one integrates freight and passenger transport and their interactions with the rest of the economy. This leads to large scale models for evaluating batteries of policy measures.

Several methods are used to model freight demand in the EU and elsewhere. An overview is presented in Department for Transport (2002a and 2002b). One of the mentioned models is MOBILEC, for which we will present one of the possible applications to be used in the SPECTRUM-program.

MOBILEC (MOBILity/EConomy) is a dynamic, interregional model that describes the interaction between transport and the economy in connection with infrastructure and other regional features. It belongs to the category of land-use transportation interaction models, but it does not have the restriction that the economy on a higher spatial scale is exogenous (for a detailed description of the model, see Appendix 3).

The system of relations (37 equations and 37 endogenous variables) produces, as most important output, time paths of the following variables:

- regional/national product, employment and investment by region;
- transport of goods by lorry, train and ship (productive mobility) within a region and between regions;
- transport of passengers by car, train and bus/tram/metro within a region and between regions, split into business traffic (productive mobility), commuter traffic and other traffic (consumptive mobility).

The model can be used for forecasting these time paths and for calculating effects of transport policy and spatial planning.

To illustrate the possibilities of the model, we give an example of a reference scenario and an extension scenario.

Improvement of infrastructure is an important tool of transport policy. The question arises how and in which extent an improvement of the infrastructure influences transport and the economy in space and time. For an adequate answer, two relationships must be taken into account:

(1) the interaction between the economy and transport: the economy influences transport and transport influences the economy;
(2) the way of financing the improvement of the infrastructure and its influence on the economy and transport; this relationship is important in case of large infrastructure projects.

A *reference scenario* is presented, where the capacity of the road infrastructure is constant in the course of time. The travel time of the road traffic depends on the utilization of the road capacity: more vehicles on a certain stretch of infrastructure imply lower speed and therefore longer travel time. Substitution for other transport modes is possible.

Then an *extension scen*ario is formulated where the capacity of the road infrastructure is extended in all regions in such a way that travel time of the road traffic does not rise in spite of the increasing road traffic. Other assumptions of the reference scenario are maintained.

The *extension scenario* is compared with the reference scenario. It shows the spatial effects the extension scenario generates, in terms of value-added and employment by region. In addition, the effects on transport of goods and passengers by transport mode are presented.

The scenarios are based on the "European Coordination"-scenario of CPB Netherlands Bureau for Economic Policy Analysis. This CPB-scenario is characterised by an economic growth of 2.75% on average per year, which will be a resulting economic growth in the reported tables for the Netherlands and Belgium. Other scenarios with other resulting economic growth are possible.

All scenarios are based on the following assumptions:

- increase of the share of labour-intensive industries (especially the service sector) in the regional product in a period of 3 years corresponding to ¾ of the rise of this share in the preceding period;
- increase of the real wage rate of 1.7 % by year;
- decrease of the average number of passengers by car with 0.3 % by year and increase of the average load by lorry, train and ship with 0.7 % by year.

We make the following additional assumptions for the reference scenario:

- constant capacity of the roads;
- constant real travel-distance cost by kilometre;
- constant travel time by train and ship.

The results are presented in Table 4.7. In the period 2000-2030, the reference scenario shows an average economic growth in Belgium of 2.71% per year and an average economic growth in the Netherlands of 2.74% per year (both simulations with results close to an average economic growth of 2.75% per year). It is accompanied with an average growth of employment of 0.94% per year in Belgium and 1.03% per year in the Netherlands. In Belgium and the Netherlands, the transport of goods by train and ship grows more than that by lorry. This means that the growth effect of the economic growth is larger that the substitution effects.

As a result of the *extension scenario*, the travel time costs of the lorry, car and bus do not rise any longer. This has a positive effect on the growth of the regional product, employment and transport by lorry, car and bus. The higher economic growth benefits also the transport of goods by train and ship.

Table 4.7 Average growth per year (%) of the real domestic product, employment and transport of goods and passengers by transport mode in Belgium and in the Netherlands in the period 2000-2030 (*)

	Belgium		The Netherlands	
	Reference scenario	Extension scenario	Reference scenario	Extension scenario
Domestic product	2.71	2.77	2.74	2.82
Employment	0.94	0.99	1.03	1.12
Transport of goods				
• by lorry	2.15	2.64	2.15	2.65
• by train	2.66	2.71	1.95	2.01
• by ship	2.79	2.85	2.32	2.39
Transport of passengers				
• by car				
• by train	0.63	1.18	0.70	1.28
• by bus, tram,	0.22	0.05	0.22	0.15
metro	-0.48	0.06	-0.46	0.08

(*) Transport growth has been calculated on the basis of the number of passengers or quantities of tonnes.

4.3 Conclusions and recommendations for case studies

In this section of deliverable D6 we have provided an analytical framework to analyse the effects of separate variables and a combination of variables with respect to freight transport. The variables take into account price settings, regulation mechanisms and investments in infrastructure.

A general model with respect to freight transport is given. The market for freight transport is represented by the demand for and supply of freight transport on the existing network. In this way it became clear that a number of elements are crucial in the determination of the impact of policy measures on freight transport, such as determination of marginal costs[9], demand for transport, price elasticity, capacity and type of commodities.

[9] For an explanation of marginal costs (marginal private costs and marginal social costs), see Blauwens, De Baere & Van de Voorde (2002, chapters 13-14).

We have quantitatively illustrated the close relationship between economic growth and freight transport demand in the short run. Instead of reducing freight transport, the aim should be to shift part of road haulage to other modes, improve the use of the existing capacity and increase, if necessary, the capacity.

In order to analyse the effects of policy measures on different modes in freight transport, a partial equilibrium model is constructed. Starting from equations for the demand for and the supply of freight transport by mode i, it was possible to derive equilibrium conditions for the different modes (with or without a capacity constraint).

A number of impacts can be studied with the constructed models, but they all require the knowledge of the demand and supply elasticities of freight transport. However, it should be clear that:

- there is a wide spread in reported elasticities;
- elasticities are not constant over time;
- elasticities are not the same for different countries, regions and for different commodity groups;
- elasticities are not symmetric, in the sense that there is a difference between the effect of price increases and decreases.

In summary, elasticities are time-specific and region specific and should therefore be considered very carefully.

Provided information about all the elasticities was available, it would be possible to quantify the equilibrium conditions. However, we should also bear in mind that the calculated effects of elasticities only give an indication of an isolated measure. It is also important to focus on indirect effects in and outside the freight sector. Therefore, several methods are used to model freight demand in the EU and elsewhere. One of the mentioned models is MOBILEC, for which an extension scenario is presented. It shows how and in which extent an improvement of the infrastructure influences transport and the economy in space and time. However, it should be clear that the development of such models is time-consuming, data-consuming and cost-intensive. New applications (e.g. long-distance freight movements across several countries) will require additional investments in development.

From the previous reasoning, it should be clear for policy makers that for freight transport, there are no ready-made practical solutions or suggestions (e.g. the mentioned differences in elasticities).

How can these results be applied to the several case studies? Each case study concerning freight will have to make a selection out of the analytical framework given. This is illustrated in the following two examples:

1. In forthcoming work of SPECTRUM an examination of capacity management within (sea) ports will be carried out. An analysis will be made of the role of slot allocation, pricing and other measures, including new infrastructure in ports (e.g. Antwerp). This work can, in particular, use some of the reported elasticities in Section 4.2.3.

2. In the case studies, the impact of new infrastructure such as the Betuwe line and the Iron Rhine will be investigated. It is clear that section 4.2.4 gives a framework to cope with this work. A scenario analysis on the basis of MOBILEC can give quantitative results and indications.

5 Impact on Transport System Performance

5.1 Introduction

Transport system performance is a measure of the efficiency of producing the supply side of transport system. It covers those transport system objectives of SPECTRUM that are not included in the previous chapters. This means that we look at the system from point of view of the government, infrastructure provider, financier and operator. At the same time we have to take into account the user benefits, as otherwise double counting may occur in the overall appraisal. A typical example is a situation where an enhanced infrastructure reduces operation costs of public transport, and part of the savings fall on the users, part on the operator and part on the government in the form of reduced subsidies.

First, we look at some fundamental concepts of transport system performance and discuss some technical matters of evaluation. Then, we look deeper to the items that should be covered. Finally, we give some practical recommendations on how all this can be done using typical state-of-the-art transport models.

Earlier studies on the subject and recommendations for including transport system performance indicators in the evaluation framework and CBA have been carried out in the APAS/Road3 studies (1994-95), EURET research programme (1995-98) and EUNET research project (1996-99).

5.1.1 Efficient production of transport supply and services

Two of the components, producer benefits *PS* and government revenue *REV*, of transport system performance are represented in the welfare (*W*) function (see SPECTRUM D4):

$$W = N.CS + (1 + ?)\,(REV + PS - b.R) - EEC \qquad (1)$$

where *N* is the number of consumers and *CS* their (average) consumer surplus. *REV* is the government net revenue and $b.R$ the total accident costs paid by the government. External environmental cost (*EEC*) is the last component of this welfare function. An important part of equation (1) is the societal value of raising government revenue $(1+l)$. Producer surplus *PS* is defined in SPECTRUM D4 as in formula (2) below.

$$PS = p.X - C(X, D, CAP, m, z) - r.K(CAP, D) \qquad (2)$$

These components are derived from building, running and maintaining the transport system and services from the owner and government's point of view. In formula (2) *p* is the price that the producer sets on the transport service. Investment and land take costs are included in the capital cost component *r.K*, where *r* refers to discount rate. Operation and maintenance costs are included in the running cost component *C*, in which *X* refers to the quantity of the infrastructure used, *m* to the external cost regulations, *z* to the safety regulation, *CAP* to the capacity and *D* to durability of the infrastructure.

The explicit assumption in equation (1) is that transport services are produced publicly (not privately) since PS is multiplied by $(1+l)$. If we want to address the private provision of transport services we need to revise eq. (1) to allow for it. This is discussed more thoroughly below.

It should be noted that the cost side of the above formulas is described in Chapters 5.2 and 5.3, the revenue side in Chapters 5.4 and 5.5. The net surpluses can then be calculated by subtracting relevant costs from corresponding revenues. The theoretical discussion and thorough description of different components and variables involved in producers' and government's surplus can be found for example in Minken et al. 2003. It should also be noted that formula (1) describes only a welfare function for the case of only one transport market. The analysis can be extended to integrate several transport markets (see for example UNITE D4, 2003).

5.1.2 Discounting

The time when an economic impact occurs can affect how its economic value is valued. In general, future impacts are discounted to present value. Discount rates reflect the time value of money, which recognizes that wealth can be invested to generate future profits (decreased costs, increased income, i.e. increased benefits), so current resources have greater value than future resources. Selecting the discount rate is particularly important when evaluating impacts that occur many years in the future, such as the benefits of a highway improvement after 30 years. The higher the rate, the more weight is given to present over future net-benefits (Litman 2003).

Transforming future annual benefits (and disbenefits) to present values is done assuming real values. Inflation is usually not taken into account. (Minken et al., 2003)

A debate exists as to the discount rate to use for human health and environmental costs imposed on future generations. Conventional discounting implies that costs many years in the future are of little concern now. It has been argued that this is not appropriate for evaluating human health risk and irreversible environmental impacts. They recommend using a lower discount rate for human health and irreversible environmental costs to give fair consideration to future generations' interests. The reader should also see Chapters 6 and 8 of this deliverable to get an overview of these matters.

The discount rate is an integral part of the cost benefit analysis, is analogous to the rate of return for private investments and represents income that might have been anticipated from an alternative investment[10]. The lower rate tends to favour investments with high initial investment costs and with most of their benefits in the future. Capital investment discount rates are typically 6-10%. These rates reflect the return capital could earn in typical alternative investments. Both the UNITE and MC-ICAM projects have examined issues concerning the discount rate. Typical European recommendations vary between 3 and 5 %, PROSPECTS Methodological Guidebook (Minken et al., 2003) recommends 5 to 8 %. There might also be differences in the

[10] It should be noticed that there are in principle to approaches concerning the discount rate: (1) a rate reflecting the time preference of private consumers; (2) a "social" rate involving a broader consideration to the choice between consumption at present and in the future.

discount rates of capital investment regarding public and private markets, which have to be recognised if private markets are involved. The discount rate of private funds is usually somewhat higher than the rate of public funds due to a higher risk associated with private funds. Sensitivity analysis using different discount rates is often envisaged to take into account uncertainty concerning the choice of the appropriate discount rate.

The cost benefit calculations span over several years, a typical period is 30 years. At the end of the evaluation period an investment will still own capital assets, called residual value, which must not be ignored. It can be included in the calculus as a benefit in the final year or discounted residual value can be subtracted from the investment cost.

5.1.3 Shadow Price of Public Funds

Shadow prices have to be applied to market prices when these prices do not reflect the true opportunity costs. Shadow prices have also been applied to the funds used to finance mitigation programmes (IPCC 2001). Public expenditures, regardless of the benefits they confer, impose a cost on society, which reflects the "marginal excess burden" of a tax policy. The marginal costs of public funds (represented by 1+*?* in the formula 1) should include the impacts of eventually reduced distortions compared with existing tax systems, as well as administration costs, compliance costs, the excess burden of tax evasion, and avoidance costs incurred by the taxpayers, but it has also been suggested that the distributional impacts of public funds collection should be included (IPCC 2001).

The marginal costs of public funds are critically dependent on the welfare loss associated with distortions caused by taxation, which is dependent on the specific tax structure. Fiscal taxation or poorly specified charges act similarly. To evaluate the true social cost of the funds it is necessary to estimate or know the marginal cost of public funds. In general there will not be one figure for this cost for the whole tax system. Each source of finance will have its own marginal cost.

Estimates tend to suggest that the marginal costs of public funds are larger in developing countries than in developed countries. In IPCC (2001) some estimates are given. It refers to results that this ratio varies between 0.48 and 2.18 for developing countries and 1.08 and 1.56 for the USA. The European Commission has used a value of 1.28 for the shadow price of public funds. In the FATIMA project, the multiplier used in the optimisation target function was 1.25 (*?=0.25* in the formula 1). The UNITE, PROSPECTS and MC-ICAM projects have discussed ratios of similar magnitude, PROSPECTS recommends *0 = ? = 0.3* (Minken et al. 2003).

As private involvement in transport infrastructure and service provision is growing, it will affect the rate (1+*?*) applied to producer surplus. One way is to separate private sector components of the calculation from the public ones and use the shadow price only on the public components. Another possibility is an approximation, where the value of *?* is reduced in order to take into account the private share of the transport provision.

5.2 Investment and land take

Investment and land take costs are typically the overwhelming immediate monetary impacts of a transport system enhancement. Their impact on transport system performance is straightforward to evaluate, and they have real monetary values. In formula (2) *r* refers to discount rate, as well as *CAP* to the capacity (often the design factor that sets the scale and cost of the project) and *D* to durability (life-span or frequency of major repairs) of the infrastructure. These form the major cost side of a typical transport project. It should be noticed that, if the investment (building) phase is long, investment costs should also be discounted to the opening year. Interest on the loans needed for investments have to be taken into account, too. Finally, the financier may vary between projects, and even in one project there may exist several investors. For example, local administration may pay for the infrastructure, but private company may invest on some long-life equipment or rolling stock.

5.3 Operation and maintenance

Often the long-term efficiency of a transport system improvement depends more on the operation and maintenance costs, represented by component *C* in the formula (2) above, than on the investment cost. These annual payments vary over the life-span of a transport scheme, and they may affect different stakeholder groups. Usually, their monetary value is clear and therefore they are easy to transform to present value with the given discount rate.

The typical stakeholders of operation and maintenance costs are government (maintenance, subsidies, toll collection, etc.) and service providers (public transport, parking, etc.). Of course the users are also affected, since they will face delay, increased risk of accident, etc due to maintenance activities, but their role is covered in Chapters 3 and 4. In different situations their roles may vary. Here the shadow price of public funds may also be applicable.

It is recommended that peak and off-peak conditions are treated separately, as the operation costs differ significantly. On the other hand, a company running buses in a region has to rate its capital investment on a vehicle fleet used during the peak situation, indifferent of the demand in the off-peak or weekend situation. Similar, temporal inefficiencies can be found in the infrastructure itself, parking place provision, urban logistics, terminals etc.

5.4 Government transport revenue

The role of the government has been to provide and finance infrastructure. The means of finance are direct provision of transport infrastructure through national budget or specific transport sector fund, or outsourcing the provision through public-private partnerships (PPP). The revenue from the transport system can come through direct cost recovery or indirect channels, such as fuel taxes, user charges for motor vehicles or value added tax for transport services.

Revenue may comprise tolls, user charges, taxes, subsidies, etc. Cost recovery is the most simplistic and intuitive model for revenue gathering for the government. Users are required to pay a fee for the services they use, in the ideal case according to the exact use of the service, but in reality based on an average flat rate fee. Thus, through user charges, based on the marginal revenue principle, the government is able to cover some of the costs of providing the transport system. In many cases pure marginal cost pricing won't cover (all) investment costs, so that the government cannot fully recover the fixed investment cost. Anyway, the inclusion of such revenues into CBA framework is quite a straight-forward exercise. The expected revenues over time through cost recovery can be discounted to present value, but only in connection with appropriate price elasticities. These are needed to take into consideration the changes in demand due to introduction of revenue raising scheme. Estimates based on pure flow data tend to overestimate the cost recovery as the number of trips is likely to change as a consequence of the introduction of the user fee.

The other dimension of government revenue is the indirect revenue, which is collected through various systems aimed at controlling the transport and related activities, or purely on fiscal basis. Fuel taxes and other taxes are the most common examples of the indirect revenue. Furthermore, the impact of an infrastructure investment on national income and on the overall economic development is of great interest as discussed in Chapter 2.4.

Government revenue is mostly based on (fiscal) taxes and (non-fiscal) charges (*REV* in formula 1). There are many details that have to be solved in each case study. The way in which VAT, commodity taxes, tolls and charges are entered into the calculus has to be decided case by case. For example, the government may hire a company to collect the charges, which leads to a different allocation of the revenue than for example in the case of fuel tax.

Part of government revenue is returned to the transport system, for example as investments or subsidies (see Sections 5.2 and 5.3 above), or used to cover other transport related costs (such as police and medical costs related to accidents, *b.R* in formula (1); see also Chapter 6). Therefore, an appraisal has to ensure that the money flows are correctly understood, double counting is avoided, and that the net revenue is the final outcome of the work. Typical interrelations are shown in Table 5.1 in order to help the appraisal work.

PROSPECTS captures government surplus as tax revenue and other revenue after expenses have been subtracted. Expenses like investment costs, infrastructure maintenance and public transport subsidies are listed as typical ones affecting local and national government.

5.5 Producer surplus

In the private sector, producer benefits are the main incentive for all activities. Producer surplus is defined in SPECTRUM D4 as in formula (2) above. It shows simply that producers receive revenue *p.X*, which can be calculated from the prices *p* and amounts of services used *X*. The rest of the terms refer again to the capital costs (*K*) and running costs (*C*), and the whole formula to net benefits.

Usually we have to consider at least items like trip fares and parking fees here, but toll fees etc. may also be allocated to (private) producers. Of course, the government may produce some of the services itself, and in certain arrangements part of the producers' revenue comes from government subsidies or purchases.

Again, PROSPECTS defines producer surplus as producers' annual revenue minus all annual costs (including taxes). Taxes are one of the elements that have to be taken as cost for one party and revenue for another, even though the net sum may be 0. All terms of producer surplus are needed in an appraisal in order to reveal distributional changes, winners and losers. Table 5.1 can again be consulted when one has to decide which terms are relevant to CBA. Only net surplus should be included.

5.6 Summary of recommendations for case studies

The following Table 5.1 summarises typical cost and revenue components needed to assess transport system performance from the government and producer point of view. The meaning of the table is to remind those involved in an appraisal work how different components of the welfare function are represented as money flows in reality. For each producer of transport service or infrastructure it is shown whether a certain term is a cost (-) or revenue (+). In practice, there may be many transfers between the different entities in the Table 5.1, which do not influence the total costs but do influence the net benefits for individual groups. PROSPECTS Methodological Guidebook (Minken et al. 2003) can also be consulted on how to enter taxes in the appraisal or how to categorise sectors or costs and benefits.

Table 5.1 Typical costs and revenues of government and producers of transport sector

	Government		Producers					Total
	National	Local	PT *) operator	Parking operator	For-warders	Carrier	Others	
Running costs			-			-		
Wages	-	-	-	-	-	-	-	
Investments	-	-	-	-		-	-	
Maintenance	-	-	-	-		-	-	
VAT	+		-	-	-	-	-	
Other taxes	+	+	-	-	-	-	-	
Transport taxes	+		-			-	-	
Charges	+	+	-	+	-	+/-	-	
Fares			+		+	+	+	
Fees				+	+	-	+	
Subsidies	-	-	+	+				
Total								

*) Public transport operator

This summary table is not comprehensive, and in many cases either new components or stakeholders are needed. Often a more detailed level is also useful, for example commodity taxes like fuel tax, or environmentally set charges have to be extracted from corresponding rows of the above table. Organisational and legal circumstances may also affect the assessment of these impacts; especially the roles of different stakeholders may differ from case to case.

If the models used in an appraisal represent the utilities of different actors correctly, the surplus of each stakeholder can be derived from the calculations. This is typical the situation for passengers in many transport models. Government and producers are usually not involved in the transport models as such. Therefore many items need to be evaluated separately using model outputs, plans and other sources as an input for the calculations. This applies especially to subsidies and taxes.

6 Measuring impacts on safety and accidents

6.1 Introduction

The aim of this chapter is to present a methodology for the calculation of accident costs. This needs to be done both for total accident cost and for marginal accident cost[11]. Policy measures or packages of measures taken by governments can be evaluated using a social cost benefit analysis. In such an analysis all the costs and benefits the measure creates are examined. Not only are the impacts on accidents but also on the environment, mobility, etc. taken into account. In order to evaluate the effect on accidents the total costs of an accident and the change in risk due to the measure[12] are needed. Hence, calculating the total cost of an accident is the first aim of this paper.

The marginal accident cost is the extra cost imposed by a user on all users (including him-/herself) and on the general public due to the traffic decision taken. Note that part of the problem is that people do not take into account all costs when they decide to take a trip or drive an extra kilometre. That part of the cost that is taken into account is called the internal cost and the part that is not taken into account is the external cost. If the driver does not bear the full accident cost, his/her private decision will not take into account all costs and hence the decision will not be socially optimal. A way to make the user take into account the external costs is to charge for the costs. This charge will be based on the marginal external accident[13] cost. Hence, the second aim of this chapter is to calculate the marginal external accident cost.

In order to present a methodology for the calculation of accident costs we at first base ourselves on the theoretical model of Lindberg[14] (2002a) to derive the total and marginal external accident cost. From this analysis the different components for calculating the accident costs are derived. Next, we explore how each of these components can be calculated. For each of the components we make a review of the relevant literature. We conclude with an example and some recommendations.

6.2 Total and marginal accident cost

6.2.1 Total accident cost[15]

We consider four types of accidents: fatal accidents, accidents with serious injuries, accidents with light injuries and accidents with only material damage. We use an index $s = 1\ldots4$ to denote these different types. For each accident type the total accident cost per accident[16] can be viewed as consisting of the willingness to pay for

[11] Note that we only calculate the marginal cost with respect to vehicle kilometres and not with respect to safety behaviour.
[12] In Appendix 4 we give an overview of different road safety measures and their effect on accidents.
[13] Note that if we want to evaluate road pricing in a CBA we need to take into account the total accident cost.
[14] The model of Lindberg (2002a) is a generalisation of the two models presented by Jansson (1994)
[15] More details on the calculations can be found in Appendix 5.
[16] The accident cost does not include the time losses which occur because an accident has happened.

reducing the accident risk to zero, both on part of the motorists themselves (a^s), and on the part of their dependants, relatives and friends (b^s), as well as the direct accident costs borne by the rest of society (c^s). Note that the direct costs (the cold-blooded part of the total accident cost) can be calculated by taking the average cost per accident of net output losses, ambulance transport and so on, whereas the warm-blooded part is harder to calculate. We come back to this issue in Section 6.3. $(a^s + b^s + c^s)$ is the relevant cost to use in a social cost benefit analysis.

We consider five different modes: cars, buses, trucks[17], cyclists and pedestrians. We denote this by the index $j = 1 \ldots 5$. Each mode can have an accident with a mode of the same type or with a different mode or with an object such as a wall or tree. We denote the other party involved in the accident by index $i = 1 \ldots 6$. i has the same elements as j but also includes immovable objects[18].

For a given mode j, the total annual cost of accidents where mode j is involved[19], TC_j, can be written as equation (1).

$$TC_j = \sum_{i=1}^{6} \sum_{s=1}^{4} A_{ji}^s (a^s + b^s + c^s) \tag{1}$$

Where A_{ji}^s is the number of accident victims of type s between mode j and i. A_{ji}^s is a function of the traffic volume of category j, Q_j and other explanatory variables, including the traffic volume of the other categories involved Q_i, i.e. $A_{ji}^s = f(Q_j, Q_i, ...)$.
Part of the accident cost is borne by users of the same type; the other part is borne by users of a different type. If q_{jj} denotes the share of total accident cost that falls on category j, total accident cost can be written as the sum of the total cost for the other users, TC_i[20] and the average cost for the own category, AC_{ji}.

$$TC_j = \sum_i TC_{ji} + \sum_i AC_{ji} Q_j \tag{2}$$

With

$r_{jj}^s = \dfrac{A_{jj}^s}{Q_j}$, the accident risk

$AC_{ji} = \sum_s q_{ji} r_{ji}^s (a^s + b^s + c^s)$

$TC_{ji} = \sum_s (1 - q_{ji}) A_{jj}^s (a^s + b^s + c^s)$

These should be included in the congestion cost.

[17] In general, the accident severity seems to increase with the weight. Hence we could divide the mode 'trucks' into different weight categories. This would not change the analysis. Lindberg (2002b) calculates the marginal external accident costs of trucks for seven different weight classes.

[18] An accident with an immovable object such as trees, walls, etc. is also called a single-vehicle accident.

[19] With involved we mean that the vehicle has been one of the parties in the accident, irrespectively who is hurt or who was at fault.

[20] In single-vehicle accidents this term does not exist, cf. if $q_{jj} = 1 \Rightarrow TC_6 = 0$

6.2.2 Internal versus external costs

There are two categories of accident costs that can be distinguished, the internal and the external costs. Internal accident costs are the costs that the driver takes into account. We assume that the driver understands his risk and consequently already bears the value to his own risk of being a victim. He also takes into account the loss for his relatives and friends. Hence the total internal cost[21] equals $\sum_i \sum_s q_{ji} \left(a^s + b^s\right) A^s_{ji}$.

External accident costs are the cost not borne by the driver. We assume that he does not take into account the value of a statistical life and the loss for the relatives and friends of the other party; hence he does not take into account $\sum_i \sum_s \left(1 - q_{ji}\right)\left(a^s + b^s\right) A^s_{ji}$.

Furthermore, he does not[22] take into account the costs for society, $\sum_i \sum_s c^s A^s_{ji}$.

6.2.3 The marginal external cost

The total marginal accident cost is the extra cost imposed by a user on all users (including him/herself) and the general public due to his travel decision. If the number of accidents does not change due to a trip decision, there is no need to charge the user. However, evidence shows that if the traffic volume rises the number of accidents rises. Hence, there is a marginal effect.

The marginal cost with respect to the traffic volume $\left(Q_j\right)$ for mode j can be written as equation (3).

$$MC_j = \sum_i \sum_s \frac{\partial A^s_{ji}}{\partial Q_j} (a^s + b^s + c^s) \tag{3}$$

The goal of accident externality pricing is to make the driver internalise the external accident cost. Hence if we want to calculate the optimal price it is this marginal external cost and not the total marginal cost that we should charge to the road user[23]. Given that we assume that the driver only takes into account $\sum_i \sum_s q_{ji} \left(a^s + b^s\right) A^s_{ji}$, the total external accident cost can be expressed as equation (4).

$$TEC_j = \left[\sum_{i=1}^{6} \sum_{s=1}^{4} A^s_{ji} (a^s + b^s + c^s) \right] - \left[\sum_{i=1}^{6} \sum_{s=1}^{4} q_{ji} (a^s + b^s) A^s_{ji} \right] \tag{4}$$

[21] This assumption can be discussed. Road users are not always fully informed about their risks, and they may disregard the fact that some persons outside the family care about their well-being.

[22] Whether c^s is external depends on the insurance system. If insurance covering costs of type c^s is compulsory, then the cold-blooded costs are internalized through the insurance premium.

[23] Note that a charge will not affect the behaviour while driving. It is possible that behaviour is a much more important trigger of accidents than the trip decisions.

The marginal external accident cost then equals:

$$MEC_j = \frac{\partial TEC_j}{\partial Q_j} = \sum_i \left(\frac{\partial TC_i}{\partial Q_j} + Q_j \frac{\partial AC_{ji}}{\partial Q_j} + \sum_s q_{ji} r_{ji}^s c^s \right) \tag{5}$$

The marginal external accident cost gives the effect on total external cost of an additional kilometre driven by j. The first element is the effect on total cost imposed on the other parties, the second element the costs imposed on other users of the same category and the third element is the cost imposed on the society.

The risk elasticity E_{ij}^s, which expresses the change in risk as the traffic volume changes, is defined as follows:

$$E_{ji}^s = \frac{\partial r_{ji}^s}{\partial Q_j} \frac{Q_j}{r_{ji}^s} \tag{6}$$

Using (6) we can rewrite (5) as follows.

$$MEC_j = \sum_i \sum_s \left[r_{ji}^s (a^s + b^s + c^s)(1 - q_{ji} + E_{jj}^s) + q_{jj} r_{jj}^s c \right] \tag{7}$$

The marginal external accident cost depends on four elements: the accident risk $\left(r_{jj}^s\right)$, the cost of an accident $\left(a^s + b^s + c^s\right)$, the proportion of the cost already borne by the examined user $\left(q_{ji}\right)$ and the risk elasticity $\left(E_{jj}^s\right)$. The marginal external cost will be high if the accident risk, $\left(r_{jj}^s\right)$ is high, if the cost per accident, $\left(a^s + b^s + c^s\right)$ is high, if most of the costs fall on the other user groups $\left(q_{ji} \approx 0\right)$, if the risk increases when traffic increases, ($E_{ji}^s > 0$) or if the cost for society, $\left(c^s\right)$ is large.

6.2.4 Remarks

First, note that in the analysis up to now we focussed on road safety. The same methodology can be used to calculate the marginal external accident costs for other modes such as maritime transport[24], trains and air traffic. However, data is much harder to find for these modes.

Secondly, the number of trips and the behaviour during these trips create the traffic safety problem. Internalisation of the marginal external cost ensures an optimal number of trips. In addition, if the marginal cost is estimated for different roads, a differentiated charge will also influence the route choice. However, an ex ante charge will never influence the behaviour during the trip. This highlights the importance of a broad traffic safety policy. Such a broader approach would result in a differentiated strategy consisting of a mix of pricing and non-pricing measures. For an example we refer to Delhaye (2003) (see Appendix 6) in which the joint use of regulation, strict liability and a tax per km is considered.

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[24] For example, Lindberg (2002c) calculates the marginal external accident costs in maritime transport on the Baltic sea.

Thirdly, the marginal cost above is based on the change in risk. This change in risk can be influenced by traffic safety behaviour, which the increased number of vehicles has forced the user to take. This change in behaviour comes at a cost, which we do not take into account in the analysis made earlier.

6.3 Calculation of the accident costs

For a cost benefit analysis we need to know the total cost of an accident $\left(a^s + b^s + c^s\right)$ for the different accident types, for road pricing we also need information on the accident risk, $\left(r_{jj}^s\right)$ and its relationship with traffic volume, the elasticity, $\left(E_{jj}^s\right)$ and on how $\left(a^s + b^s + c^s\right)$ is allocated between user groups, q_{jj} .

6.3.1 Cost of an accident

The accident cost $\left(a^s + b^s + c^s\right)$ consists of three components [25].

a) The value of a statistical life

The most important element in the cost of an accident is the value of statistical life (VOSL). The valuation of a life can be controversial, but is necessary to make an evaluation. Several techniques can be used to derive the value of a statistical life.

Decisions made by government

A first way to value a life is to look at the decisions made by government. If the government spends X euro in order to safe Y lives, the implicit value of a life equals X/Y or more. However, decisions are not always made rationally and coherently. This method leads to variations in the value of life ranging from 55 euro to more than 2 million euro.

Life insurance and courts

Insurances can give an idea about the value of life. One assumes that the cost of dying or being injured is directly related to the sum for which one is insured. However, this is only true if the sum covers for the full loss in output. This is unlikely, since the sum is meant for the relatives. Moreover, one cannot conclude that people without insurance attach no value to their life.

The same problems arise when one looks at the compensations ruled by courts. The advantage is that, as with insurance, there is also a valuation for non-mortal accidents. However, they are also meant for the relatives and moreover, vary a lot between courts.

[25] Based on De Blaeij et al (2000), Jones-Lee (1994), Schwab, N. and Soguel, N. (1995).

Human capital approach

There are two variants of the human capital approach. The first approach equals the value of a life to the discounted value of the future production, which disappears because of death or injury. The European Union uses this first approach and uses a value of 1 million euro. However, this does not take into account the future consumption, or the fact that people also value their life without caring for national production. The second approach again takes the output but subtracts the own consumption. Only the pure economic value is considered. However, this will lead to a negative value for the aged, which is for most people ethically not acceptable.

Welfare economic approach

The previous methods have the disadvantage that they do not take into account the willingness to pay of the victim to prevent pain and suffering. A more indirect method is looking at this willingness to pay for a reduction in risk. The value of a statistical life (VOSL) is then determined by equation (8)

$$VOSL = \frac{WTP}{\text{change in risk}} \tag{8}$$

Generally speaking, two groups of valuation techniques can be distinguished: revealed preferences and stated preferences. The revealed preference method is based on observed choices actually made by people. These choices entail an implicit trade-off between money and risk. Given the lack of data on real risk-money choices in the transport sector this method is not used a lot in transport. The stated preference method asks the respondents in a more or less direct way about their willingness-to-pay for a hypothetical change in accident risk. This method is often referred to as the 'contingent valuation' method (CVM). However, note that there are some questions about the reliability of the results since various problems of CVM have been identified[26]. We give some examples to give an idea of the kind of problems involved. Known problems are: strategic, survey design and hypothetical biases, embedding and scope effects, etc. An example of strategic behaviour is free riding, whereby a respondent may pretend to have less interest in a given collective activity than he really has. The stated willingness-to-pay may also depend upon the circumstances of the presentation, this is the information given, the format used (for example, bidding games versus open-ended questions). The hypothetical character makes that people do not actually have to pay. This could lead to irresponsible behaviour giving too high or too low values because people may believe that their answers will have no consequences. Embedding and scope effects refer to the tendency of respondents to report the same willingness-to-pay, regardless of the size of the improvement.

Following the latest developments of studies of VOSL (see above), which includes risk-risk studies, the relative value between different degrees of injuries can also be derived. Earlier recommendations include the ECMT (1998), which estimate the risk

[26] For more information on problems with the CV-method we refer to Hanley and Spash (1993), Lesser et al (1997) and Carson et al (2001).

value for severe injuries at 13% and for light injuries at 1% of the risk value of fatalities[27].

The mainstream opinion today is that the value of a statistical life can be estimated through asking a sample of the population for their willingness to pay[28]. UNITE summarises a number of recent studies on the willingness-to-pay. Hence we follow their recommendation and propose an average European value of statistical life of 1.5 million euro. The value depends on the purchasing power and thus will be different between the Member States. The value is in line with other recent estimates but at the lower end of previous estimates. As a sensitivity test a higher VOSL of 2.5 million euro could be used. This value represents a less conservative approach and is at the upper end of reliable state-of-the-art studies. As a lower bound a value of 0.75 million euro can be used. This represents a rough lost gross production approach. Table 6.1 gives an overview of the proposed values for the cost component a^s of an accident.

Table 6.1 Proposed UNITE VOSL by country and compared to official values (consumer value- € 1998)[29]

Country	Official values in use[(A)] Million euro	UNITE VOSL Million euro	Serious injury Million euro	Slight injury Million euro	(Official-UNITE)/ Official %
Austria	1.52	1.68	0.218	0.017	10%
Belgium	0.40	1.67	0.217	0.017	312%
Denmark[(B)]	0.52*	1.79	0.233	0.018	244%
Finland	0.89*	1.54	0.200	0.015	73%
France	0.62	1.49	0.194	0.015	141%
Germany	0.87	1.62	0.211	0.016	87%
Greece[(B)]	0.14	1.00	0.130	0.010	588%
Ireland	1.04	1.63	0.212	0.016	57%
Italy	n.a.	1.51	0.196	0.015	-
Luxembourg	n.a.	2.64	0.343	0.026	-
Netherlands	0.12	1.70	0.221	0.017	1269%
Norway[(B)]	1.49	1.93	0.251	0.019	29%
Portugal	0.04	1.12	0.146	0.011	2896%
Spain	0.07	1.21	0.157	0.012	1625%
Sweden[(B)]	1.48*	1.53	0.199	0.015	4%
Switzerland[(B)]	n.a.	1.91	0.248	0.019	-
United Kingdom[(B)]	1.53*	1.52	0.198	0.015	1%
Hungary[(B)]	n.a.	0.74	0.096	0.007	-
Estonia[(B)]	n.a.	0.65	0.084	0.006	-

[(A)] Based on Nellthorp, Mackie and Bristow (1998). Note that Trawén et al (2002) also gives an overview of official values for fatal accidents used by different countries. In their overview values can be found both for the VOSL as for c^s.
[(B)] Not in Euro zone, Exchange rate of 24 November 2000 used
* Latest available values from Ternoven (1999) have been used (For Sweden SIKA (2000)). Corresponding EUNET values are DK 0.79; FIN 1.33; N n.a.; S 1.80; UK 1.11

[27] Persson et al (2000) use 16% for serious injuries and 1.5% for slight injuries; official figures for Finland are 0.5%, respectively 0.1%; for Sweden 15.4% and 0.7%; for the UK 11.4% and 0.9% and for Norway 16.7% and 2.9%. (Lindberg (2002a))
[28] Lindberg (2002a)
[29] Derived from Table 2 in Lindberg et al (2002a). Note that for SPECTRUM a different base year will be used and hence that these figures need to be adapted. In UNITE it is assumed that values grow with real incomes, based on an elasticity of 1.0. (Nellthorp et al (2001))

b) The value for relatives and friends

The affected individual may have relatives and friends who care about his exposure to risk and consequently have a willingness to pay for his risk reduction. Whether we should include a value for pain, grief and suffering of relatives and friends depends on the form of altruism that occurs. This is discussed by Jones-Lee (1992). If altruism means that one is concerned only for the safety of other people, then one should include a value for the pain, grief and suffering of relatives and friends. However, if altruism means that a person is concerned for the general welfare of others (which depends not only on their safety, but also on other factors), then it should not be included in order to avoid double counting. Also, if people are purely selfish, this value should not be included. However, it has never been proven that preferences are purely selfish or purely altruistic. For intermediate forms of altruism, Jones-Lee recommends a ratio of b/a around 0.1-0.4[30].

Since we do not know if the user does not already take this value into account in stating his willingness to pay we do not include this element in our analysis.

c) Cost for society

The additional road user also causes costs to society. These include medical costs, police costs, material damages, the net-output loss and possibly the reduction of labour productivity. Trawén et al (2002) shows that this cost can differ greatly between countries.

Following UNITE conventions we assume that these costs equal approximately 10% of the risk value.

6.3.2 The accident risk and elasticity

In order to calculate the marginal external cost we also need to know the accident risk. We know that the number of accidents per 100.000 inhabitants and per 100.000 vkm varies substantially between the different countries in the E.U[31]. Hence the accident risks will also vary widely between Member States and transport modes. The risk values for a country are easily obtained from the statistics. One needs to know the number of accidents per year and the vehicle kilometres per year. While accident statistics may be good in many cases, although there may be underreporting, the possibility of finding more specific information on exposure (e.g. for different modes, road types, etc.) is in general very poor.

[30] This ratio is also found in other studies, e.g. Needleman (1976) and Schwab et al (1995).
[31] The figures on the number of people killed per 100.000 inhabitants range from around 6 for the UK and Sweden up to more than 20 for Greece and Portugal.

The literature[32] is less clear about exactly how the number of accidents increase if the traffic volume rises[33]. On the one hand, the probability of collusion increases with traffic volume. On the other hand people may also adapt their driving style and drive more carefully. Ex-ante we cannot say which effect predominates. This is a question for empirical research. The increase in the number of accidents may be proportional to the increase in the volume or it may increase progressively or degressively.

Figure 6.1 shows the different possibilities of the relationship between accidents and traffic volume graphically.

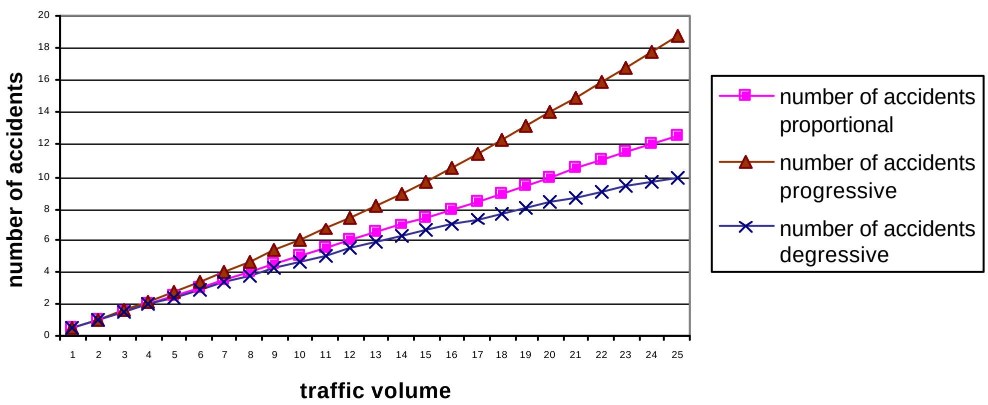

Figure 6.1 Relationship between accidents and traffic volume.

Early literature often states that the number of accidents increases progressively with road traffic. If the relationship is progressive the accident risk, which equals the number of accidents per vehicle kilometre, will increase if there is more traffic and the risk elasticity, which equals the percentage change in risk when the traffic increases by one percent, will be positive. Newbery (1988) argues that if road users do not change their behaviour and the road system stays constant "the probability of accidents depends on the number of passings, which means that accidents will increase as the square of the traffic flow". This means that $A_{ji}^{s} = Q_{j}^{2}$, which implies a risk elasticity $E_{ij}^{s} = 1$. However, he then states that this is unlikely and that the relationship will be somewhat weaker. He proposes a risk elasticity E_{ji}^{s} of 0.25. Vickrey (1968, 1969) cites evidence that $A_{ji}^{s} = Q_{j}^{1,5}$ which implies that $E_{ji}^{s} = 0,5$ and not twice as is implied by the square rule. If the number of accidents increases in proportion to the traffic volume, the accident risk is constant and the risk elasticity

[32] See Satterthwaite (1981) for a survey of earlier literature, Vitaliano and Held (1991) for later studies
[33] Note that speed and the variance of speed also influence the accident risk. A change in traffic volume will influence the level of speed. For example, if traffic is already very dense, more traffic will decrease the level of speed. We can calculate the effect on accident risk of a change in speed due to a change in traffic volume. If we know the traffic volume and the congestion function we can calculate the effect of a change in volume on the level of speed. We can then use the function provided by Elvik (2000). This function gives the effect of a change in speed (from current speed to speed) on the accident risk: $\text{effect on accident risk} = 1 - \left(\frac{speed}{\text{current speed}}\right)^{pr}$ with *pr* equal to 4 for fatal accidents, 3 for accidents with serious injuries, and 2 for accidents with light injuries.

will take the value zero. In practice, it is often assumed that the relation is proportional. Recent literature such as Lindberg (2002a) and Fridstrøm (1999) suggests that the relation is degressive. The accident risk then declines and the elasticity will be negative. Fridstrøm (1999) for example finds that risk elasticity with respect to overall traffic volume equals -0.089. However, this is only the partial effect. If one takes into account the effect of increased traffic on the traffic density the risk elasticity equals -0.50. This means that an additional user reduces the accident risk for all other users. Think for example of a situation where pedestrians cross the road. If more pedestrians cross the road, their risk to be hit by a car may decline. Lindberg (2002b) for example finds that the risk elasticity for trucks is also negative and ranges between the different weight categories from -0.91 till -0.63.

What can explain these different findings? Most importantly, the risk elasticity depends on the initial situation. For example, if traffic is already very dense, additional traffic will influence the level of speed. If speed drops, the accident probability might decline and the severity of accidents will certainly decline.

6.3.3 Theta

We also need to know how the accident cost is allocated between the user groups. We will assume that in accidents involving the same type of vehicles, accident costs are split equally. For accidents between a car / heavy vehicle (buses and trucks) and an unprotected road user (bicyclists and pedestrians) we assume that the unprotected road user bears all the costs and for accidents between cars and heavy vehicles we assume that the car bears 80% of the costs[34].

6.4 An example

We illustrate the theory on marginal external accidents by means of an example for car-bicyclist accidents. This example[35] is based on the illustration given in Jansson (1994).

The first element that we need is the accident costs format $\left(a^s + b^s + c^s\right)$. Table 6.2 gives the cost of an accident for the European Union.

Table 6.2 Accident values and its components, (1000€, 1998)

Cost components	Fatality	Severely injured	Light injured
A	1500	195	15
b	0	0	0
c	150	19.5	1.5
A+b+c	1650	214.5	16.5

[34] These assumptions are reasonable. Similar figures, based on real data for Sweden can be found in Lindberg (2001) and in Lindberg (2002b)

[35] For the calculation of the marginal external accident cost of heavy good vehicles and of maritime transport we refer to Lindberg (2002b) and Lindberg (2002c)

According to Jansson (1994) in relatively low-risk countries like Sweden, in urban areas, approximately one unprotected road user is killed and ten are seriously injured per 100 million motor-vehicle kilometres. These figures can be twice or three times higher in other European countries. Hence we calculate the marginal external cost for three different values of $\left(r_{ji}^{s}\right)$. Fridstrøm (1999) presents, among others, a regression model for accidents between motor vehicles and bicyclists, which results in a risk-elasticity of -0.576 with respect to motor traffic volume. As a sensitivity analysis we also calculate the marginal external cost for an elasticity equal to nil and to 1. We already mentioned that we assume that the 'weak' category of users can be expected to bear all the costs of the collision (q =0).

We now have all elements to calculate the marginal external cost as given in equation (7). The results can be found in Table 6.3.

Table 6.3 MEC for collusions between cars and cyclists (Euro per vehicle km)

Values of E_{ji}^{s}	Number of killed and seriously injured unprotected road users per 100 million motor vehicle kilometres		
	1 and 10	*2 and 20*	*3 and 30*
-0.576	0.016	0.032	0.048
0	0.038	0.076	0.114
1	0.076	0.152	0.228

Source: Delhaye, E (2003b)

If we want that the driver takes into account the accident risk he imposes on the bicyclist, we should charge him, depending on the assumptions, 0.016-0.228 euro per vehicle kilometre.

6.5 Summary of recommendations for case studies

In Chapter 6.3 where we discussed the calculation of the accident cost we also mentioned the values we recommend. In Chapter 6.4 we constructed a small example to show how the calculation should be done in practice.

In this last section we briefly repeat our recommendations. We propose that for the accident costs $\left(a^{s}+b^{s}+c^{s}\right)$ the values of UNITE are used. Table 6.1 gives the proposed values for different countries of the EU. For the calculation of the accident risks, r_{ji}^{s} we recommend to use national data. If the case studies have data on the risk elasticity, E_{ji}^{s} this should be used. If not, a sensitivity analysis using different values for E_{ji}^{s} is recommended. For the division of costs between the parties involved in an accident it is probably hard to find data, therefore we made some suggestions on which assumptions are reasonable.

7 Measurement and treatment of externalities

7.1 Introduction

The aim of work reported in this chapter is to study effects of policies in terms of externalities they generate. At first we briefly identify the main issues we are dealing with regarding transport policy externalities. Secondly, we discuss the assignment of values for these externalities. In this section, a special emphasis is placed on proposing recommended (range of) values for various externalities. It should be noted, that not all externalities can yet be fully monetised, there are physical, environmental, health or technical impacts that have to be assessed using non-monetised methods.

We will discuss the externalities based on the traditional view, defined in Baumol and Oates (1988:17-18): "An externality is present whenever some individual's utility or production relationships include real variables, whose values are chosen by others without particular attention to effects on this individual's welfare." Further, "the decision-maker whose activity affects others' utility levels or enters their production function, does not receive (pay) compensation for this activity an amount equal in value to the resulting benefits (or costs) to others". In short, externality is a form of uncompensated effect on a utility function or a production set.

This chapter will look at the following externalities: Noise, congestion, air pollution and visual intrusion. This chapter broadens the work in the previous chapter on accidents with a number of other important externalities. Externality research has concentrated primarily on a limited set of external costs, i.e. those associated to the emission of air polluting substances, to accidents, to global warming and, concerning transport, to congestion. Congestion was discussed already in the context of passenger transport. Noise pollution has been extensively investigated, but the current body of knowledge is still insufficient, while other externalities are altogether largely under-documented, such as e.g. visual intrusion, community severance, water and soil pollution and odours. Additional research, both theoretical and empirical (e.g., through ad hoc case studies) is needed (Ricci 2003). We shall return to these issues in the conclusions section.

This topic has been approached in many previous studies, most notably within the European Transport Systems in CAPRI, IMPRINT, PETS (PETS 2000) and in the UNITE-project that dealt with marginal costs of transport and various categories of externalities. The present study will give an overview of estimates for costs of externalities based on previous research and produce practical guidelines on and recommendations for values to use when they are not pre-determined. This will be of relevance particularly to Accession countries, where such valuation is less progressed than in the EU-15 countries.

7.2 On quantifying and valuing the externalities

In order to determine the marginal costs and benefits, we need to value the impacts of externalities. In cases where direct market values do not exist, these types of valuations are based on Hicksian measures of compensating or equivalent variation. These variations can be determined by a number of measures (PETS, 2000):

- Willingness to pay for an improvement

- Willingness to pay to avoid the deterioration
- Amount of compensation needed to accept the deterioration
- Amount of compensation in the absence of an improvement

As we have noticed in the connection of value of time studies in Chapter 3, two main groups of methodologies to valuation are the revealed preferences method (RP) and the stated preference method (SP). Revealed preferences use people's real reactions in real markets and stated preferences use responses to direct questions about valuations. Theoretically, both methods are sound so no preference is given in this respect. However, it can be easily seen that detecting revealed preferences is likely to be more difficult than detecting stated preferences.

These valuations have their problems, which should be mentioned here to demonstrate the limitations of the methodology. For instance, using willingness to pay as an indicator gives more weight to people with higher incomes, though this can be solved by assigning weights to income groups. Similarly, willingness-to-pay studies will be limited in size to small samples, which means that coming up with statistically valid data is time-consuming and costly.

7.3 Congestion

In this chapter, congestion as an externality will be analysed, keeping in mind that we already have discussed the values of time in greater detail when we looked at passenger transport in Chapter 3. There is a strong link between these two chapters, as it is necessary to revisit the congestion from the perspective of passenger transport.

The marginal road congestion costs have been addressed in UNITE both at the urban and inter-urban level in several case studies: four corridors (Paris-Brussels; Paris-Munich, Cologne-Milan and Duisburg-Mannheim) for passenger and freight transport at inter-urban level, and four case studies (Brussels, Edinburgh, Helsinki and Salzburg) at urban level. (see Appendix 2.1)

The methodological approach adopted varies from the application of speed-flow relationships defined in the EWS manual for Germany at inter-urban level to traffic models with the definition of speed-flow curves per link at the urban level.

Marginal congestion costs have also been estimated by the INFRAS/IWW 2000 study at the European level through the use of continuous speed-flow relationships for different classes of roads and vehicle types, where the basic input is provided by the European Road Traffic database.

Other approaches are based on exponential congestion functions (under the assumption that the area under consideration has homogeneous traffic conditions, see De Borger and Proost, 2001) and on speed-flow relationships calculated from the UK National Road Traffic Forecast database, as in Sansom et al. (2001). This study calculates speed-flow curves by area types (London and conurbations) and road types (motorways, trunk and principal and other). However, it calculates marginal costs for existing rather than optimal traffic volumes that therefore are much higher than estimates at the optimum.

Discrepancies, particularly at the urban level, can be explained by the adoption of different time values, as well as by specific methodological aspects that can hamper comparisons (the UNITE urban marginal congestion costs for instance are expressed in pcu/km, the other studies in vkm/km). In fact, the UNITE urban case studies include smaller cities such as Edinburgh and Salzburg while estimates from other studies relate to large conurbations such as London, with presumably higher congestion costs. Furthermore, congestion costs are strictly related to the specific characteristics of the routes, i.e. traffic volume, infrastructure bottlenecks, etc.

Finally, it should be noted that although calculation of marginal congestion cost is fairly straightforward, setting up a charging system using this ideal principle is nearly impossible. This is because each vehicle will create a marginal cost different from another that implies that the congestion charge should be distinct for every car.

7.4 Noise

Noise can be a significant externality of transport, when noise generated is directly affecting large populations. This holds especially in large urban areas. There is also great difference if the noise is experienced inside a house or outside as the building insulates the noise. To assess the level of traffic noise, the level of sound (L) as a function of traffic volume should be constructed, implying that the noise is decreasingly growing with the traffic load (Ricci and Friedrich 1999). L can be expressed as

$$L = \alpha_1+\alpha_2 \text{ Log}[Q(1+\alpha_3 p)] + \sum D$$

Where α_1, α_2, and α_3 are constants, Q is the traffic volume, p is the share of HGV in the traffic volume and D are additive correction factors to take into account the nature of the road and the value of the permitted speed.

Cost function C is defined as

$$C=\beta \, [\exp(\lambda \, (L-L_0) - 1]$$

Where β, λ are coefficients, L measured in dB(A) is the actual noise level people are exposed to and L_0 is the threshold beyond which noise is considered to be disturbing.

Substituting L for latter expression we obtain

$$C = \beta \, \{\exp [\, \lambda(\alpha_1+\alpha_2 \text{ Log } (Q(1+\alpha_3 p)) + \sum D) - L_0] -1\}$$

The derivative of C with respect to Q is

$$MC = \Phi \, Q^n$$

MC is the marginal cost, Φ is the function of the threshold L_0 and of other parameters such as terrain profile and distance from the noise source. n can be expressed as a non-integer function of λ and therefore it also varies with L_0.

We can see that MC may increase or decrease with Q depending on shape of the cost function derived from WTP values.

There have been some recent studies on noise, most notably in the UNITE project. Some of the marginal costs for various vehicle types in different case studies in Germany, based on UNITE results are presented in Appendix 2.2.

In PETS, a more simplified method of pricing was suggested (PETS, 1999). For various categories of transport, the recommendations were given as euros per passenger or tonne kilometre.

Table 7.1 Values for noise by transport category in Euro.

	Euro per 1000 passenger kms	**Euro per tonne kms**
Cars	4.5	-
Buses	4.2	-
Passenger trains	3.1	-
HGV	-	12.7
Freight train	-	4.7

Source: PETS (1999)

The figures above are from 1995 and should be deflated to reflect the year of analysis according to research needs. The choice of base year is usually the same that is chosen for discounting the benefits of a project. Updating cost estimates to the base year is most commonly done using a deflator such as Consumer Price Index (CPI) or Gross Domestic Product (GDP) change.

For the Accession countries, the OECD has published some guideline figures for noise (OECD 2003, 18) where the average willingness to pay value per dB(A) is set to 30 EURO per dB(A) average per household (exposed) - adjusted by GDP per capita (The GDP/capita is measured at purchasing power parities).

As can be seen, we have a variety of figures from which to choose. For HGV, the value appears to be around 10-25 euros per tonne kilometre in urban areas, for buses around 2-6 euros for passenger kilometre and for cars less than that. When there is location specific information available, this should be utilised. When such information is not available, it is recommended that values reported above should be used adjusted to the case that is subject to study and with a clear documentation of how these values were derived.

7.5 Emissions and air pollution

There have been a number of studies addressing the emission and pollution externalities. We present a summary of some of the most relevant studies below.

When there are no alternative values to use (suggested by the National Administrative bodies for use in the official appraisals of national projects or derived from relevant national literature) we recommend values given below. Since there are a number to choose from, it is important to document the source used as well as the reason for choosing the particular values.

In addition to costs due to local pollutants, costs due to emission of greenhouse gases, of which CO_2 is the most important, are relevant on a global scale. The cost of CO_2 emitted is directly related to the energy consumption in transport and thus fairly straightforward to calculate. The main problem is to set an adequate monetary value for the damage caused, and for meeting the Kyoto target. The values reported range from 5€ to 50€ at present and up to 200€ per tonne of CO_2 avoided in the long run depending on the size of markets and sectors included in the studies (UNITE D11, 2003 and Minken et al.,2003).

Road

Table 7.2 below shows some possible unit costs from different sources in the recent literature. There may exist differences in the definitions for ”rural” for instance, which may account for some of the variations in figures.

Table 7.2 Cost in Euro per emitted kilo of pollutants from transport

	SO_2		**NO_x**		**VOC**		**PM_{10}**		
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Small town	Rural
Eyre	52	7	13	9	3	3	92		14
EUNET		1.7		4.5			185*		
ECMT			8	4	8	4			0
Eriksen	9	2	8	4	8	4	206	25	0
SIKA	27	2.3	10	6.8	8.5	3.4	864	216	0

*$PM_{2.5}$
Source: PROSPECTS D2, 2002

External costs of transport have been calculated for various European cities in the ExternE project (PETS 1999) and in the UNITE case studies including both urban and inter-urban case studies. In Appendix 2.2 some of these results are summarised for different vehicle types. These values are good examples of the range of values depending on the specific circumstances, e.g. the size of the city, road type, etc. These studies give also reference for approximation of the air pollution and greenhouse gas emissions, as we are again dealing with a range of possible options.

In the projects FATIMA (2000) and PROSPECTS (2003) overall kilometre based values for three externalities, pollution, noise and accidents were used. These values for four cities are shown in Appendix 1.4.

Rail

The environmental costs of rail transport are highly dependent on the energy source used for traction. Countries with a high level of diesel traction have higher air pollution and global warming costs than countries with a completely electrified network. Countries using nuclear power to generate electricity for traction have the lowest costs, because emission costs from nuclear power production are small compared to costs from fossil power production that produces large amounts of airborne emissions. As an example of rail environmental marginal external costs the results from German and Italian case studies from UNITE project (UNITE D11) are shown in Appendix 2.2.

Air

In UNITE (D15) as an example of a typical European flight, marginal costs of a flight between London and Berlin were studied.

In this example the shares of the total costs of externalities related to landing and take-off activities (pollution, global warming and noise) were nearly the same namely one third for each: 49€ for air pollution, 53€ for global warming and 59€ for noise. The cost of cruising the 930 km distance was valued at 231€ and is dominated by CO_2 emission cost. Altogether this flight of a medium range aircraft (Boeing 737-400) from Berlin to London was estimated to have an airborne emission cost of 42¢ per aircraft kilometre.

Direct air pollution emissions were valued at approximately 38€ per LTO cycle (landing and take-off cycle) for Heathrow and 42€ for Tegel. Global warming costs were 49€ and 45€ per LTO cycle for London and Berlin respectively.

Methodological advances

For valuing impacts of noise and air pollution, there have been suggestions to use the impact pathway analysis. In the impact pathway methodology the final result is reached by steps: (1) determination of the amount of pollutant emitted, (2) calculation of increased pollutant concentration in all affected regions and physical impacts due to that concentration and (3) finally economic valuation of these impacts. For the impacts that are greatly dependent on spatial characteristics (population and housing densities, building materials used, terrain profiles etc.) this methodology focuses the costs right there where they occur, for instance impacts on health.

Where possible, this is a recommendable option, as it is likely that the willingness-to-pay studies will be too expensive to conduct for case studies and project evaluations, and the use of nationally set figures can be misleading. In this respect, whilst we propose to use the values or ranges of values given here, we would also like to acknowledge the possible future developments in the valuation.

7.6 Visual intrusion

"Transport infrastructure and mobile plant is frequently visually intrusive and often far from pleasing" (Button 1995).

Visual intrusions resulting from transport projects and initiatives have not been researched very thoroughly. However, the most suitable approach is to carry out a willingness-to-pay study in a geographically relevant area to assess the visual intrusion created by a transport initiative. Some guidelines for values of nature and landscape are provided in Banfi et al. (2000), where values for marginal and average costs are given. Table 7.3 summarises these values.

Table 7.3 Values for nature and landscape, marginal and average cost in euro per passenger/ tonne kilometre.

Transport Mode	**Marginal Cost (Average Cost) Euro Per 1000 Pkm/Tkm**
Road	
Car	0-1.8 (2.5)
Motorcycle	0-1.8 (2)
Bus	0-1.3 (0.8)
Light delivery vehicle	0-23 (23)
Heavy delivery vehicle	0-8.9 (2.2)
Rail	
Passenger	0-0.8 (0.7)
Freight	0-0.3 (0.5)
Aviation	
Passenger	0-2.9 (1.7)
Freight	0-8.5 (8.5)
Water freight	0-0.5 (0.5)

Source: Banfi et al. (2000).

As the table shows, there is a great range in values observed available for analysis. This is due to great differences in traffic systems and their surroundings (urban and inter-urban). Using these values as a basis of estimates is possible, when no other information is available.

7.7 Physical externalities

The physical externalities have multiple dimensions, so assessment using a single indicator is not likely to capture the full impact.

As an example, let us consider changes in community interaction, which results from a transport network going through a settlement. It is the suppressed trips caused by the transport infrastructure that are hard to measure. In fact, development of methodology to cover this aspect of transport infrastructure building has not been considered one of the key future developments. In a similar manner, the effects of increasing amount of disposed old cars are an important concern as a physical externality, yet the costs of disposal are not always borne by the user of the vehicle. In fact, in some countries a person giving away a car to disposal is granted a lump sum pay, which is related to other externalities created by the vehicle, namely safety and emissions.

More abstract, yet possibly physical feature of the network is the vibrations that the network creates and which may potentially affect buildings. Again, these types of effects are difficult to measure and mostly likely the assessment must rely on estimates only (see IASON project, Mackie 2001, for a more detailed discussion of network effects).

To summarise, the physical externalities are most difficult ones to capture in the assessment, and due to their relatively small importance the developments in methodology are not considered worth the effort.

7.8 Conclusions on the value recommendations for externalities

Regarding the purpose of the work here, we have been able to identify a good range of values for externalities to be used in the case studies. It has been a challenging task to identify the recommendable values from the vast literature available. We have decided to rely on the most recent, and, in some cases, most thorough research available. It is clear that the UNITE project is one of the leading projects in the field, but we also find findings from the INFRAS/IWW study particularly useful for the purposes of this work package.

Our recommendation is to use country-specific or region-specific values for monetising the externalities, whenever such values are available and they are reliable. When such values are not available or there is a reason to believe they are not applicable for whatever reason (different research hypothesis, out-of-date figures, modelling requirements) we recommend referring to the most recent European level research for average values. Recommending a single value only for overall European-wide research is not a feasible option as there are so many factors that will influence the choice of the value. Whatever values are used, the choice and specification of values used should be transparent, to allow comparison of the research results with other research.

It has become evident that we still need more detailed information regarding some of the externalities. In this respect, particularly the treatment and valuation of noise and visual intrusion are problematic. When it comes to areas such as physical externalities (other than visual intrusion), we have to even more rely on secondary sources of information from the literature. These areas are of marginal magnitude in the project appraisal, but their importance can become significant from the European Value Added point of view. These issues will change the European human geography and social cohesion, both of which can lead to surprisingly big changes in interaction and location patterns in the European level.

8 Measurement and treatment of equity

8.1 Introduction

The two broad classes of objectives in SPECTRUM are economic efficiency and equity. Efficiency-enhancing measures like marginal cost pricing and optimal investment have important distributional impacts. Thus the trade-off between economic efficiency and equity is central to decision-making.

Deliverable 4 of SPECTRUM (Mayeres, et al 2003) provides an overview of the equity implications of optimal rules for pricing, infrastructure and regulatory policies. It also provides some general guidelines on how to address equity considerations through revenue recycling and if necessary through the design of a sub-optimal package of instruments that sets a desired trade-off between economic efficiency and equity.

Whether the introduction of efficient transport policies leads to an increase in inequality is an empirical question that needs to be addressed by designing and applying equity indicators. The purpose of this task is to provide practical guidance on how inequality should be defined and measured. In doing so, we have widened the scope from Deliverable 4, where inequality across income groups was considered, to the broader issue of how to measure inequality across individuals and households living in different regions and having different socio-economic characteristics. In Section 8.2 we provide a short discussion on how to define equity. Before the quantification of inequality we need to make a decision about the unit of observation and the definition of the dimension along which inequality is measured. Income is an important dimension and is often associated with utility. These issues are covered in Section 8.3.

Section 8.4 addresses inequality measures, poverty measures and some alternative approaches for measuring accessibility. Inequality measures have both a normative and a descriptive content. Hence we need to evaluate these measures against a number of desired properties for their qualities. We cover these properties and go through the classification of measures of inequality and provide examples in each class along with a summary of their properties. Some of the objectives under equity in SPECTRUM are related to the provision of a "minimum level of transport services". For these objectives we rely on the literature on the measurement of poverty. Since accessibility is an important variable in the provision of transport infrastructure and services, we proceed by defining accessibility and alternative approaches for the measurement of accessibility in this section.

Section 8.5 will address two alternative approaches for addressing inter-generational equity considerations. We summarize the main recommendations in the context of the SPECTRUM case studies in Section 8.6.

8.2 Defining Equity

The most central issue in the assessment of equity is related to how equity is defined. Equity can be defined along many dimensions such as justice, rights, treatment of equals, capability, opportunities, resources, wealth, primary goods, income, welfare, utility and so on (see Sen, 1982, 1992). Sen (1992, p12) states "that every normative theory of social arrangement that has at all stood the test of time seems to demand equality of *something*- something that is regarded as particularly important in that theory. The theories involved are diverse and frequently at war with each other, but they still seem to have that common feature." Sen continues by suggesting that demanding equality in one space implies inequality in some other space. An important ethical issue is related to the *equality of consideration*. Sen suggests that "the need to defend one's theories, judgements, and claims to others who may be directly or indirectly involved, makes the equality of consideration at some level a hard requirement to avoid." Moreover, the relative advantages and disadvantages that people have compared with each other, can be judged in terms of many different variables, e.g. their respective incomes, wealth, utilities, resources, liberties, rights, quality of life, and so on. On human diversity Sen states that "The plurality of variables on which we can possibly focus to evaluate interpersonal inequality makes it necessary, to face, at a very elementary level, a hard decision regarding the perspective to be adopted. This problem of choice of the relevant focal variables is crucial to analysing inequality."

It is beyond the scope of this task to provide an overview of the way different social philosophies have defined equity and to compare these. What is relevant for our work is that different aspects of equity are important for different groups in a society and it is important to provide measures for the evaluation of their concerns and to reflect their views.

To start with we should clarify the distinctions between *formal* equality and *outcome* equality. Formal equality requires all equals to be treated equally. Yet one has to be aware of the choice of variable along which equal treatment is defined. Is it all polluters who should pay for their contributions or is it the club of car users who demands exclusive right on the revenues raised from their activities. The polluter pays principle implies equal treatment of all polluters, while motorists-should-not-pay-more-than-they-receive principle demands equal treatment of all taxpayers. Outcome equality can imply unequal treatment. Increasing accessibility for peripheral regions and accommodation of facilities for elderly or the disabled are examples where outcome equality is demanded (see Langmyhr, 1997, Minken and Ramjerdi, 2003).

The issue of equity considerations in the context of transport has received extensive attention, especially more recently related to congestion pricing. It is outside the scope of this task to cover this vast literature. We refer to a literature review on this subject by Eliasson and Lundberg (2002). This body of research has different focus. Some addresses the distributions of economic gains and losses for different groups of users, usually by income, and suggests how to calculate these. Some have focused on alternative schemes for redistribution of the toll revenues in order to address equity concerns. Others have focused on the identification of different stakeholders such as consumers, producers and operators, and subgroups among stakeholders that are affected differently by a policy. An example of the latter type of research is the work by Langmyhr (1997). He examines the case study of the Norwegian urban tolls and identifies equity considerations of different subgroups among stakeholders. He also makes an attempt to identify the type of "equity measure" that applies to their concerns and the "variable" along which inequality should be measured. There are a few studies that address the quantifications of inequalities formally and weight these against efficiency in an objective function. Examples of these are the EU funded research projects AFFORD, MC-ICAM, PROSPECTS and UNITE (see Fridstrøm, et al 2000; Minken et al, 2003; Mayeres et al., 2003).

8.3 Unit of observation and income

Before giving a description of inequality measures, we need to define a unit of analysis. In a social context the unit of analysis can be an individual or a collective unit such as a nuclear family, women, elderly, disabled, a region, etc. The choice of the unit depends on the interpretation of the inequality measurement. In some context it is natural to adopt an individual as the unit. For example when we are looking at exposure to pollutants. In other contexts, e.g. when we are examining the distribution of wealth or income, it might be more useful to adopt a collective unit such as a household. Furthermore, it is often a wish to evaluate inequalities along a certain dimension in terms of between- and within groups such as between genders, regions, etc. Coherence and homogeneity are the important criteria in the selection of collective unit.

The association of income level with welfare is a common practice in economics. Income, earned and unearned, relates to an arbitrary time unit and it excludes past accumulation or future expectation. It also excludes benefits received from publicly provided services, such as public libraries, health, education, etc. A main reason for the choice of income as a proxy for welfare is that information on personal or household income is generally available and easier to interpret than wealth or lifetime income. It is also a common practice to use a household as the unit of analysis in this situation. This relates to the economies of scale associated with consumption in a household. As an example a household of two adults needs less than twice of the income of a household of one adult to achieve the same level of welfare. This calls for the adjustment of household income for comparison and *equivalence scales* are used for this purpose. Different research and empirical studies have addressed how to relate equivalence scales with demographic variables that define a household such as number of adults, number and ages of the dependents in a household. The construction of equivalence scales is rooted in the identification of minimum needs. Expert judgement is a more suitable approach for the recommendation of suitable values for equivalence scales. The OECD's recommendation is to base these scales on the assumption that the first adult in a household gets a weight of 1.0 and a weight of 0.7 is assigned to each additional adult in the household. Children of up to 17 years old get a weight of 0.5 each. The following table summarizes the OECD's recommendation.

Table 8.1 OECD's recommended equivalence scale

Household type	Equivalence scale
Single	59
Single with 1 child	90
Single with 2 children	117
Couple	100
Couple with 1 child	130
Couple with 2 children	160

8.4 Properties of equity measures

Different measures of inequalities reflect different perception of inequality. The sets of weights that different views attach to transfers at various points in a distribution are different. That can result in contradictory ranking of a given pair of distributions (see Kolm, 1969; Atkinson, 1970; Sen, 1973). In this sense inequality measures have both a normative and a descriptive content. These measures can be used to describe the differences among a population with respect to a given variable such as income, but they can also represent the manner in which these differences should be measured. Hence these measures are evaluated against a number of desired properties.

In the following we summarize a number of axioms that can be used when selecting measures of inequality (see Harrison and Seidl 1994; Myles, 2000). These axioms are used for the construction of the axiomatic measures of inequality.

The Symmetry or anonymity axiom requires the inequality measure for a given income distribution in a given population not to be affected by the order in which the individuals are labelled. In other words it is not important who is rich and who is poor. This axiom seems very obvious. All the measures that are described in the following sections satisfy this axiom.

The Axiom of transfer or *Pigou-Dalton principle* requires that a transfer of income from a rich person to a poor person should reduce the measured inequality as long as the income of the rich person stays higher than the poor person after the transfer. This view was originally expressed by Pigou in 1912 and shared by Dalton in 1920. The Pigou-Dalton principle is an important property that any acceptable measure of inequality should satisfy.

The Principle of population requires the inequality measure to be independent of the size of the population.

The Scale invariance axiom or *relative inequality aversion axiom* demands that the measured inequality should not change if all members of a population get the same proportional increase in incomes. Kolm (1976) regards this as a (politically) rightist view[36].

The Translation invariance axiom or *absolute inequality aversion axiom* requires that the measured inequality should not change by changing all incomes by the same amount as long as the changes would not lead to a negative income. This is regarded as a (politically) leftist view[37].

The Decomposability axiom requires that there should be a coherent relationship between inequality in the whole population and its constituent parts. The basic idea is that it should be possible to define the inequality measure of the total population as a function of inequality within the constituent parts and inequality between the subgroups.

There are numerous other axioms that set specific requirements on the properties of a measure of inequality. Among these are *intermediate inequality aversion axiom* and *Lorenz dominance axiom.* Intermediate inequality aversion axiom provides a link between scale invariance and translation invariance axioms. Lorenz dominance axiom requires that the Lorenz curve of two distributions do not intersect.

8.5 A classification of inequality measures

There are different approaches for the classification of inequality measures. The following is among the most common approaches (see for example Myles, 2000 and Cowell, 1977).

1. Statistical
2. Welfare
3. Axiomatic

Statistical measures examine the distribution of any variable in a given population such as income. Examples of these are: range, variance, measure of variation, log variance, Gini measure and Theil's entropy measure. *Welfare measures* rely on welfare economics and incorporate equity concerns into the welfare function. A*xiomatic measures* are derived by addressing the properties that a satisfactory measure ought to have.

[36] Assume a population with a given income distribution. This view suggests that the degree if inequality remains the same if all incomes gets the same proportional increase. Take an individual in the population with an income of 1000 and another with an income of 1. Now assume that the income of all individuals is doubled. The one with an income of 1000 now has 2000 and the one with an income of 1 now has 2. This view suggests that inequality is not changed, while the difference between incomes of these two individuals has almost doubled.

[37] Assume that the income of all individuals is increased by the same amount. Take an individual in the population with an original income of 1000 and another with an original income of 1. The one with an income of 1000 now has 1500 and the one with an income of 1 now has 501. This view suggests that inequality is not changed. Compare this example with the example given in the previous footnote. Obviously this view is left compared with the previous view that is considered right.

These measures can be applied for the evaluation of inequality of any vector or distribution of observations, even non-economic data such as the distribution of the ambient level of pollutants or accessibility over an area.

In the following we will briefly describe a few measures in each class. More details on these measures are available in Appendix 7.

8.5.1 Statistical measures of inequality

Range, relative mean deviation, variance, coefficient of variation and log variance are among these statistical measures (see Sen, 1973 and Cowell, 1977). Cowell discusses these measures in detail and gives an evaluation of these against the properties we outlined earlier. A yardstick for the evaluation of the suitability of any statistical measure is its sensitivity to changes in a distribution pattern. In this section we will only describe the *Gini measure* and the *Theil's entropy measure*.

The Gini Measure

The *Gini measure* may be derived by the construction of a *Lorenz curve*. The Lorenz curve was introduced in 1905 and is a powerful graphical method for illustrating the inequality in a given wealth distribution. A Lorenz curve is constructed by organising a population in an increasing order of their incomes (wealth, or any other vector) and by assigning to each individual the proportion of total income earned by that individual and those who earned less.

Figure 8.1 illustrates a Lorenz curve of income for Norway in 1995. Note that if everyone in the population were to have the same income, the Lorenz curve would be the diagonal connecting the points (0, 0) and (1, 1). This diagonal line is referred to as the equity line.

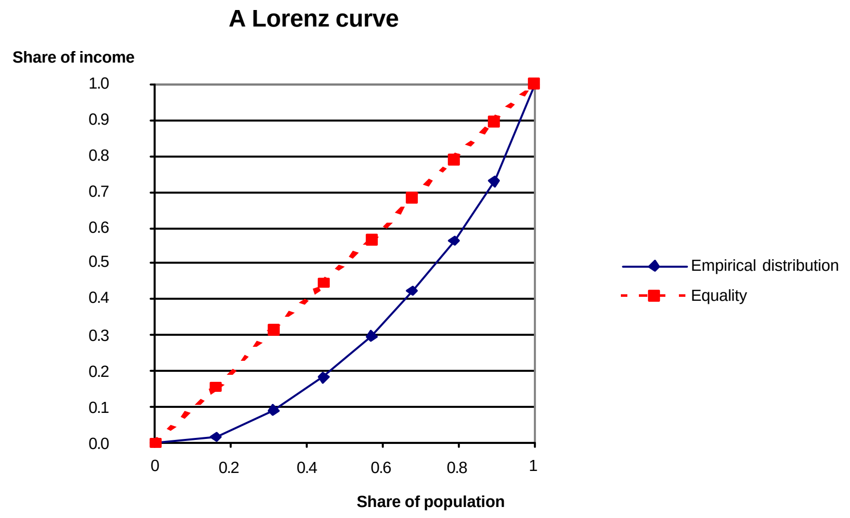

Figure 8.1 A Lorenz curve for the taxpayer population of Norway 1995

A popular way of expressing the Gini measure is by the following formula:

(1) $$G = \frac{1}{2N^2.\overline{Y}} \sum_{i=1}^{N} \sum_{j=1}^{N} | Y_i - Y_j |$$

where:

- G is the Gini measure
- Y is income
- N is the number of observations on income and
- $\overline{Y}$ is the mean level of income

This construction shows that the Gini measure takes a value between 0 and 1. If the area in the box in Figure 1 is normalized to 1, the Gini measure is then twice the area that lies between the Lorenz curve and the equality line.

The Gini measure satisfies the transfer, the population and the scale invariance axioms.

Theil's entropy measure

The class of entropy measures are based on information theory. The entropy of a system can be defined as the average information content of that system. The Theil entropy measure is the difference between the entropy measure for the actual income distribution and the entropy measure for equal incomes (Theil, 1967). The following formula shows the Theil entropy measure, T.

(2) $$T = \frac{1}{N} \sum_{i=1}^{N} \frac{Y_i}{\overline{Y}} \log(\frac{Y_i}{\overline{Y}})$$

The appeal of the entropy-based measures is their property of decomposability. The Theil entropy measure meets the population, the transfer and the scale invariance axioms.

8.5.2 Welfare measures of inequality

The implicit social welfare functions that the statistical measures of inequality are embodied in have an unsatisfactory nature (see Myles, 2000). In contrast, a welfare-based measure starts with an explicit social welfare function.

This class of measures can be applied for the comparison of inequality of a given pair of income distributions. Another approach is to directly respond to the distributional concerns by adopting an explicit form of a social welfare function and the choice of a desired inequality aversion parameter. In the following, we will briefly present Atkinson-Kolm and Kolm measures.

Atkinson-Kolm index of inequality

Kolm (1969) and Atkinson (1970) introduced the concept of "*equally distributed equivalent income*" for the comparison with the average income in order to measure inequality. The equally distributed income is defined as the income level that if it were to be enjoyed equally by all in a society, would produce the same level of social welfare as based on the observed income distribution. Their motivation was to satisfy the translation invariance axiom.

The *Atkinson's index,* A, also referred to as the *Atkinson-Kolm index,* for the measurement of inequality takes the following form:

$$A = 1 - \frac{Y_{EDE}}{\overline{Y}}$$

where:
Y_{EDE} is equally distributed equivalent income,
$\overline{Y}$ is the average income
The Atkinson's index can be presented by the following formula with a particular form of utility function (see Apendix 7).

(3) $$A_{\varepsilon} = 1 - \left[\frac{1}{N} \sum_{i=1}^{N} \left[\frac{Y_i}{\overline{Y}} \right]^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}$$

N is the total number of households. The parameter ε addresses inequality aversion.

The Atkinson-Kolm index meets the population, the transfer and the scale invariance axioms.

Kolm's measure of inequality

Kolm (1976) developed his measure by introducing another social welfare function, often referred to as a "leftist" social welfare function, in order to satisfy the translation invariance axiom. The Kolm's measure of inequality is given by the following formula.

(4) $$K_a(Y) = \frac{1}{\alpha} \log \left(\frac{1}{N} \sum_{i=1}^{N} \exp(\alpha(\overline{Y} - Y_i)) \right) \text{ where } \alpha > 0$$

The parameter α addresses inequality aversion.

The Kolm's measure satisfies the population, the transfer and the translation invariance axioms.

8.5.3 Axiomatic measures of inequality

These measures are mathematically constructed in order to meet a set of desired properties for the measurement inequality. The focus of axiomatic measures has often been the decomposability property. Among the class of decomposable measures we present Shorrocks' generalised entropy index.

Shorrocks' generalised entropy measure index

Shorrock's generalised entropy index (Shorrocks, 1980) is among the class of additively decomposable inequality measures. The following formula describes this index.

$$S_c(Y) = \frac{1}{N}\frac{1}{c(c-1)}\sum_{i=1}^{N}\left[\left(\frac{Y_i}{\overline{Y}}\right)^c - 1\right], \; c \neq 0 \text{ or } 1$$

(5) $$S_0(Y) = \frac{1}{N}\sum_{i=1}^{N}\log\frac{\overline{Y}}{Y_i} \;, \; c = 0$$

$$S_1(x) = \frac{1}{N}\sum_{i=1}^{N}\frac{Y_i}{\overline{Y}}\log\frac{Y_i}{\overline{Y}}, \; c = 1$$

Where c is a parameter that is sensitive to transfers. Note that when $c = 1$ the Shorrocks' generalised entropy index, $S_1(Y)$, is identical to Theil's entropy index.

Shorrock's generalised entropy index satisfies the transfer, population and scale invariance axioms. This is generally true for all entropy-based measures.

In Appendix 7 we present the decomposed Shorrocks' generalised entropy measure into between- and within- segments and some recommendations for their use.

8.5.4 A summary of the inequality measures

The equity measures used in SPECTRUM needs to address both horizontal and vertical dimensions[38]. By "horizontal" inequity we mean changes in ranking of a pre-policy welfare distribution to a post-policy welfare distribution. By vertical dimensions we mean the decomposition of an equity measure into within and between segments in population or regions. By using income as a proxy to welfare it is possible to allocate the changes in the net-benefits of a policy to different income groups. Hence we end up with two income distributions: the initial income distribution and the income distribution that results from a policy implementation. In this manner we can evaluate the equity implications of that policy.

There are two alternative approaches available to respond to equity considerations. One approach is to respond directly to the distributional concerns by adopting an explicit form of social welfare function and the choice of a desired inequality aversion parameter. This approach is adequate if the equity concerns is not extended to the evaluations of within and between groups inequalities. For example, if we are not concerned with the impacts of a policy within and between regions, or within and between segments of the population such an approach would be appropriate.

In Section 8.5.2 and Appendix 7 we have provided some examples of suitable social welfare functions, namely those suggested by Atkinson (1970) and Kolm (1969), for this purpose. The difference between the performance of the Atkinson and the Kolm social welfare functions can be related to the extreme values in a distribution (Decoster and Schokkaert, 2000). Since the inequality aversion parameter sets the desired trade-off between equity and efficiency, it is important to evaluate the results for different inequality aversion parameters for presentation to the decision-makers.

[38] Note that horizontal inequality has a loose definition compared with its more strict definition in the literature on the measurement of welfare and inequality.

The second approach is to apply an inequality measures for the comparison of inequality of a given pair of income distributions. The choice of a measure should be based on the availability of data and the qualities we demand from a measure[39].

Theil's entropy measure or Shorrocks' measure is an appropriate measure when the decomposition of inequality into within and between segments of a population or regions is desired and feasible. Otherwise, the choice of the measure relates to the scale variance versus the translation invariance properties. Even though translation invariance is a desirable property, a measure like the Gini measure or Theil's entropy measure is often simple to use in practice.

Table 8.2 A summary of the properties of inequality measures

Measure	Definition	Properties				
		Transfer	Population	Scale invariance	Translation invariance	Decomposability
Gini	Eq (1)	Yes	Yes	Yes	No	Weak ***)**
Theil's entropy	Eq (2)	Yes	Yes	Yes	No	Yes ***)**
Atkinson-Kolm	Eq (3)	Yes	Yes	Yes	No	No
Kolm	Eq (4)	Yes	Yes	No	Yes	No
Shorrocks	Eq (5)	Yes	Yes	Yes	No	Yes ***)**

***)** see Appendix 7

For the application of any of the inequality measures it would be desirable to have information on the income distribution of the population in a case study. In that case the change in the income of an income group can be approximated by the net-benefits (in monetary terms) occurring to that income group after a policy is implemented. For the breakdown of the measured inequality into within and between segments we need to have additional data related to these segments, such as income distributions by gender or regions.

Equity concerns might be related to how the net-benefits of a policy differ among different segments of a population or over different locations in the study area. A decomposable measure is necessary for this purpose. Furthermore, the measure should handle negative values. Note that net-benefits could be negative.

An example of the application of the equity measures to non-economic data in SPECTRUM is related to the changes in the distribution of emission of pollutants over the area of study. It might even be feasible to evaluate the changes in terms of within and between segments of the population. The segments can be defined with respect to the socio-economic characteristics of the population or by locations in the study area. Obviously, a decomposable measure is called for this evaluation.

[39] Shorrocks and Slottje (2002) suggest that when the Lorenz dominance criterion is met, all the measures of inequality in Table 2 provide the same ranking when applied to the comparison of inequality of a given pair of income distributions. They also point out that Lorenz dominance is rarely confirmed. The Lorenz dominance criterion is met when the Lorenz curve of the distributions do not intersect.

8.6 Measurements of poverty

Some of the objectives in SPECTRUM are formulated in terms of the provision of a minimum acceptable transport services for all or for a specific segment of population or region. Examples are the provision of a "minimum level of accessibility" or the provision of a minimum acceptable transport services for elderly or for disabled. For the analysis of these objectives we rely on the literature on the measurement of "poverty". Poverty measures are usually applied to income, but as in the case of inequality measures, one can apply these to any vector or distribution of observations, even non-economic data.

The definition of a *poverty line* is central for identification and measurement of poverty. A common definition of poverty line is the level of income below which a household is defined as "poor". Poverty is discussed in relation to income and welfare. It is common to consider poverty in either *absolute* or *relative* terms. The distinction between the two has important policy implications. While the concept of absolute poverty suggests time and place independence, the concept of relative poverty is not independent of time and place. The latter concept depends on the standards and norms of a given society.

In this section we summarise three measures: the Head-count ratio, the Poverty gap and the Sen measure.

Head-count ratio

The head-count ratio, H, is simply the ratio of the number of people with income Y below poverty level z, to the total population N:

(6) $$H = \frac{Q}{N}$$

where Q stands for the number of people with income $Y_i \leq z$

The head-count ratio is not sensitive to the extent of the poverty shortfall per person.

Poverty gap

Let us define the *poverty short fall*, G, as $G_i = z - Y_i$. Then the following formula defines the poverty gap, I.

(7) $$I = \frac{1}{Q}\sum_{i=1}^{Q}\frac{G_i}{z}$$

Sen measure

By their definitions, neither H, nor I are sufficiently informative about the description of poverty for a given population. Sen (1982) develops his measure to address the shortcomings of the previous two measures, described by the following formula

(8) $$S = \frac{1}{(Q+1).N.z}\left[z.Q(Q+1) + \overline{Y}_Q Q^2 \left(G - \frac{Q+1}{Q} \right) \right]$$

where:

$\overline{Y}_Q$ is the mean income of the poor and $G = 1 - \frac{1}{\overline{Y}_Q.Q^2} \sum_{i=1}^{Q} \sum_{j=1}^{Q} \left| Y_i - Y_j \right|$

The Head-count ratio provides information on the percentage of the people below the poverty line. It is not sensitive to the extent of poverty shortfall per person. The Poverty gap does not address the number of people below the poverty line. It provides information on the percentage of their mean shortfall from the poverty line. The Sen measure addresses the shortcomings of the two former measures of poverty[40].

The application of these measures in the context of SPECTRUM relates to the objectives that are formulated in terms of the provision of minimum acceptable transport services for all or for a specific segment of population or region. Take the example of the provision of a minimum accessibility for all the regions of an area. First, we need to define a variable that measures accessibility. Let us assume that we can construct a measure that determines the accessibility of a region (Section 8.5.6 will address accessibility measures). The most important task is to make a decision about the "poverty line" or the minimum acceptable accessibility[41]. Once the minimum accessibility is defined, it is possible to apply any of these measures to evaluate the number and the extent of the shortfall of accessibility in regions of the area.

Another example of the application of the poverty measures is related to the changes in the distribution of emission of pollutants over the area of study. When the concern is related to the extent to which a part of the population is exposed to an unacceptable ambient level, we need to use any or all of the above described poverty measures.

8.7 Accessibility

Accessibility captures the benefits from transport infrastructure and services. Hence accessibility measures should only be applied in the context of the evaluation of equity implications of a policy at a spatial level.

There is no universally acknowledged definition of accessibility. In a spatial context the separation of locations, by some distance, seems to be applicable to the different definitions.

[40] Note that Equation 8 addresses both the differences between incomes and the number of persons below the poverty line.

[41] Politicians and planners often refer to "the provision of minimum level of accessibility for regions" and "the provision of minimum level of transport services for segments of population". However, these "minimums" are difficult to quantify.

Until recently, increase in "accessibility" was limited to local, regional and national levels. With the emergence of the European Union more and more countries have joined or are about to join the common market, which has resulted in an immense increase in the size of the market. Access to this market for the peripheral states is of considerable importance. The basis for this inspiration has been the principles of equity and efficiency, which requires all the member states to benefit from the new market.

Economic activities have spatial dimensions. The presence of social and economic activities creates demand for interaction among individuals or firms. The transport cost to these activities and the time constraint facing individuals or firms limit the geographical scope of their activities. Characteristics of individuals or firms limit the type of activities that are useful for them to have interaction with. Hence, accessibility can be defined over at least four dimensions: land use that determines the distribution of activities over space; transport related costs; time constraints facing individuals and firms and finally, the characteristics of individuals and firms.

Various indicators with different theoretical underpinning and different degrees of complexities have been proposed and used in empirical studies of accessibility. The choice of an indicator depends on the purpose of study and the availability of data. For an excellent review and examples of the applications of these measures see Geurs and Ritsema van Eck (2001). Baradaran and Ramjerdi (2002) provide a classification of the theoretical underpinnings of accessibility measures with examples of the application of some of these measures to a European level. In this section we provide a brief review of a few accessibility measures. These are: the travel cost approach, the gravity or opportunities approach, and the utility-based approach. Appendix 8 describes alternative accessibility measures and provides some practical guidance for the measurement of accessibility.

8.7.1 Travel cost approach

This class of accessibility measures captures the ease with which any activity j ($j \in L$) can be reached from a particular location i, given a particular transport infrastructure and services. The following formula describes this class of measures.

$$A_i = \sum_{j \in L} \frac{1}{f(c_{ij}, \beta)} \quad (9)$$

where

- A_i is the measure of accessibility at location i
- L is the set of locations
- $f(c_{ij},\beta)$ is the deterrence function
- c_{ij} is a variable that captures travel cost between i and j
- β is an estimated parameter

8.7.2 Gravity or opportunities approach

A great number of accessibility measures are in this class. This approach attempts to address the behavioural aspects of travel. The earliest attempt is associated with Hansen (1959, p 73) who suggested that accessibility is the "potential of opportunities for interaction". The potential of opportunities is closely related to gravity models. This measure can be expressed by the following formula.

$$(10) \qquad G_i = \sum_{j \in L} \frac{W_j}{f(c_{ij}, \beta)}$$

W_j stands for the mass of opportunities available to i at location j (e.g. employment, population, etc.).

8.7.3 Utility-based measures

This class of measures has its roots in the application of random utility maximisation (RUM) for travel demand modelling. Ben-Akiva was the first to formulate a utility-based measure of accessibility. Ben-Akiva and Lerman (1979, p. 654) suggest, "Accessibility logically depends on the group of alternatives being evaluated and the individual traveller for whom accessibility is being measured." This is in contrast with the gravity-based approach that all individuals at a given location experience the same level of accessibility, regardless of their perceived utility of alternatives. The following formula describes a utility-based measure of accessibility:

$$(11) \qquad A_i^n = \underset{i,j \in L}{Max} U_{j|i}^n = \frac{1}{\mu} \ln \sum_{j \in L} \exp(\mu(v_j^n - c_{ij}^n))$$

where

A_i^n is the measure of accessibility at location i for individual n

$U_{j|i}^n$ is the utility of travel to location j given the individual n is located at i

v_j^n reflects attractions at j

c_{ij}^n is the travel cost between i and j

μ is a positive scale parameter that is estimated

It is common to refer to Eq (11) as "logsum". The advantage of this approach is its underpinning in behavioural theory and that accessibility can be expressed in monetary terms. Williams (1977) points out that utility-based accessibility is linked to consumer welfare measures. The application of the above formula for the calculation of accessibility is restricted to a logit formulation of demand model for travel and the assumption of the non-presence of income effect. In the presence of income-effect the different welfare measures (Hicksian equivalent variation, EV, and compensating variation, CV and Marshallian Surplus) will not coincide. McFadden (2001) provides an overview of the recent developments in RUM and provides alternative approaches for the calculation of a "correct" welfare measure. Among these approaches is the closed formulation derived by (Karlström 1999) for the calculation of EV and CV.

Among these measures the travel cost approach is the least demanding with respect to data. Different functional forms can be used for f( ) in Eq (10) [42]. See Appendix 8 for the choice of variable c_{ij}. A gravity approach partly captures behavioural aspects of

[42] Examples are $f(c_{ij}) = c_{ij}^x$, $f(c_{ij}, \beta) = e^{\beta c_{ij}}$ and $f(c_{ij}, \beta) = \frac{c_{ij}^\beta - 1}{\beta}$.

travel, yet is more demanding on data than the travel cost approach. Appendix 8 provides some suggestions for variables that can be used as proxies to attraction variable, W_j (e.g. population, employment etc.). The utility-based approach has the advantage of measuring accessibility in monetary terms. Yet in the presence of income-effects a "correct" calculation of this measure is more complex. An additional disadvantage of this approach is its high demand on data. In practice a utility-based measure is only feasible when a travel demand model system based on RUM is available for the case study.

8.8 Inter-generational equity

Individual time preference might give too little weight to more distant benefits. That is what Pigou (1920) attributed to "our defective telescopic faculty". The energy crisis of 1973 and social and economic consequences of climate change and related policies in the 1990's brought focus to the question of appropriate discount rates for projects whose effects will be spread out over hundreds of years. Portney and Weyant (1999) summarise some of the prevailing views as follow. There is an agreement among experts on the use of standard procedure for evaluation of projects with timeframes of forty years or less and to discount future benefits and costs at some positive rate. Beyond this time horizon experts divert in their approach. Some suggest to use different discount rates for different time horizons, more specifically, a smaller discount rate for a more distant future. Among these are Arrow (1999), Weizman (1999) and Kopp and Portney (1999). Recently, a lower discount rate for impacts after the 30th year has been adopted as standard UK practice (http://www.hm-treasury.gov.uk/Economic_Data_and_Tools/greenbook/data_greenbook_index.cfm).

Solow (1999) points out that a non-constant discount rate will subject the policy path to time inconsistency (see also Beltratti et al. 1998, for a formal definition of time consistency). However, others such as Heal (2000) points out that there is no reason to require time consistency in decision-making involving many generations. Ramsey (1928), Schelling (1999) and others even question the validity of application of the standard welfare-theoretic approach to decision-making with intergenerational consequences.

There are views on this subject, such as the one developed by Chichilnisky (1996) and shared by Heal (2000), that are not covered by Portney and Weyant.

Deliverable D4 of SPECTRUM (Mayeres et al, 2003) focuses on the use of an appropriate discount rate for addressing the intergenerational equity concern. This approach has been used in the research project MC-ICAM.

Minken (1999) has developed an alternative for addressing intergenerational equity concerns by relying on the theoretical frameworks developed by Chichilnisky and Heal for addressing sustainability. He proposes an objective function OF for the appraisal of the sustainability of strategies in the following general form:

(12) $$OF = \sum_{t \in t^*} \alpha_t (b_t - c_t - I_t - \gamma_t g_t) + \sum_{i \in I \& t \in t^*} \mu_{it} y_{it}$$

where

$$\alpha_t = \alpha \frac{1}{(1+r)^t} \qquad \text{when } 0 < t < (t^*\text{-}1)$$

$$\alpha_t = \alpha \frac{1}{(1+r)^t} + (1-\alpha) \text{ when } t = t^* \text{ and } 0 < \alpha < 1$$

t^* is the target year for the achievement of sustainability
r is a discount rate
a, is the intergenerational equity parameter, reflecting the relative importance of welfare at present as opposed to the welfare of future generations,
b_t and c_t are benefits and costs in year t, including user benefits, producer surpluses, benefits to the government, and external costs
I_t stands for investment, singled out as a special type of cost
γ_t is the shadow cost of CO_2 emission, reflecting national CO_2 targets for year t,
g_t is the amount of CO_2 emissions in year t,
μ_{it} is the shadow cost of reaching the year t target for sub-objective i, $i \in I$, and
y_{it} is the level of indicator i in the year t.

This approach has been used in PROSPECTS (see Minken et al 2003). See Appendix 9 for a further discussion on this approach.

8.9 Summary of recommendations

The purpose of this task is to provide practical guidance on how inequality should be defined and measured.

Equity has different forms and aspects and can be defined along different dimensions. Hence it is quite important to determine as clearly as possible what the equity concerns are; to identify the population, or segments of population who are concerned with a particular aspect of equity; the dimension along which equity is important for that particular population or segments of population. We also need norms and principles for the evaluation of the impacts of a policy on equity. These tasks require close cooperation and consultation with decision-makers and stakeholders. The planner should not make decisions on what aspect of equity is important to address or make normative decisions on behalf of the decision-makers and stakeholders. The technical issues related to the choice of a particular welfare function, an inequality measure, a poverty measure or an accessibility measure follows rather easily, once we have decided on the aspects of equity that we are concerned with and the norms that we need to use for their evaluation.

The calculation of any of the measures of inequality that were discussed in this chapter requires the calculation of the changes in welfare for different segments of a population or for different regions in the study area. SPECTRUM's Deliverables 4 and 6 have addressed in detail how to go about the calculation of the changes in welfare of consumers and non-users. A prerequisite for the calculation of the changes in welfare of the different segments of a population in practice is the ability of the model (system) that is used in a case study to identify these segments.

Examples of intra-generational equity concerns are:

1. Comparison of the welfare of the affected population before and after the implementation of the package. One can address this concern by either the choice of an appropriate welfare function or the use of an inequality measure. By choosing a welfare function we need to use an inequality aversion parameter that would reflect the decision-makers' trade-off between efficiency and equity. Since there is no guarantee that there would be a consensus among the decision-makers on the "trade-off", we probably need to show the results for different inequality aversion parameters. The same concerns apply to the use of an inequality measure. Any of the inequality measures have a normative content. They either have scale invariance property or translation invariance property, which should reflect the decision-makers views. Furthermore, if the choice of the inequality measure involves a decision about the inequality aversion parameter, that choice should also coincide with the decision-makers' trade-off between equity and efficiency.
2. Evaluation of the changes in welfare into within and between segments of population, such as gender or different locations of the study area. In this case we need to apply a decomposable measure.
3. Equity concern might be related to how the net-benefits of the package differs among different segments of a population or over different locations in the study area. Note that in this case, net-benefits could be negative, so the measure should be able to handle this. Only translation invariant measures are.
4. The equity concern can be related to the changes in the distribution of emission of pollutants over the area of study. One issue is to evaluate the changes into within and between segments of the population. The segments can be defined by the socio-economic characteristics of the population or by locations in the study area. Obviously, a decomposable measure is called for this evaluation. Another issue is related to the evaluation of the extent to which a part of the population is exposed to an unacceptable ambient level. In this case we need to use any or all of the poverty measures.
5. The equity concern can be related to the changes in accessibilities of different locations within the study area. These concerns can be formulated in terms of the provision of a minimum acceptable transport services for all or for a specific segment of population or region. In this case equity should be evaluated along the dimension of accessibility. By choosing an appropriate accessibility measure we can calculate the changes in distribution of accessibility over a region. The most important task is to make a decision about the "poverty line" or the minimum acceptable accessibility. Once the minimum accessibility is defined, it is possible to apply the poverty measures to evaluate the number and the extent of the shortfall of accessibility in regions of the area.

There are numerous other examples of equity concerns that can be treated in a similar manner.

For addressing inter-generational equity concerns we suggest to either use a lower discount rate for addressing the interests of distant generations or to use Minken's approach (Minken et al.,2003).

Applying and computing equity measures in a transport context is novel. The SPECTRUM case studies will have an experimental character in this respect. We think it is important to concentrate on simple issues that are explored in depth rather than output a lot of unanalysed data. Consultations with decision-makers and stakeholders on the interpretability and usefulness of the measures will be vital[43].

[43] It is important to discuss the properties of the measures used. For example if an inequality measure meets the relative inequality or absolute inequality property (see Section 8.4). Another example is related to the provision of the minimum level of services or the minimum level of accessibility. The politicians should make the decisions about these levels. The same discussion applies to the choice of a measure for accessibility.

9 General conclusions for and specific comment on the case studies

9.1 General conclusions for the case studies

9.1.1 Safety and other externalities

We propose that for the accident costs $\left(a^s + b^s + c^s\right)$ the values of UNITE are used. Table 6.1 gives the proposed values for different countries in the EU. For the calculation of the accident risks, r_{ji}^s we recommend to use national data. If the case studies have data on the risk elasticity, E_{ji}^s this should be used. If not, a sensitivity analysis using different values for E_{ji}^s is recommended. For the division of costs it is probably hard to find data, therefore we made some suggestions on which assumptions are reasonable. We will assume that in accidents involving the same type of vehicles, accident costs are split equally. For accidents between a car/ heavy vehicle (buses and trucks) and an unprotected road user (bicyclists and pedestrians) we assume that the unprotected road user bears all the costs, and for accidents between cars and heavy vehicles we assume that the car bears 80% of the costs.

Congestion, noise and emissions are the other externalities that should be covered in all case studies and also monetised for the CBA as there are national values available. These are well captured with state-of-the-art transport modelling and related appraisal methods. Especially noise requires a detailed description of land use. Vibration, visual intrusion, fragmentation etc. should be covered if, for example, natural preservation areas will be affected. If monetising is difficult, they should be treated in the MCA, but often descriptive analysis is the only way to present them for the decision-makers.

The recommendation is to use country-specific or region-specific values for monetising the externalities, whenever such values are available and they are reliable. When such values are not available or there is a reason to believe they are not applicable for whatever reason (different research hypothesis, out-of-date figures, modelling requirements) we recommend referring to the most recent European level research for average values.

The use of average values derived from one source for appraisal in another case may create large errors. Transport demand, transport system and surrounding land use have huge impacts on the values. Therefore, each case should analyse externalities with care and imply local values when available.

9.1.2 Conclusions for passenger case studies

Concerning passenger transport, there are numerous components that contribute to the net benefit received from a transport policy option. Each case study has to consider which of them apply to that particular study.

The idea of the rule-of-the-half is useful in defining the net benefits of passengers. If there are changes in generalised costs the calculations are quite straightforward.

Another possibility is to use the transport model parameters (logsum) as a tool for measuring the benefits.

Travel time components

In-vehicle time is the time spent travelling in the vehicle. *Walking and cycling times* are also considered to be 'in-vehicle time' when these modes are used as the main mode.

Access/egress time is the time in origin to reach and in destination to leave the main mode of transport. The concept of access/egress time is somewhat unsteady. Normally, it means walking or cycling time to the stop of the first public transport mode or car park and in destination accordingly. Sometimes, especially in long distance travel, it can mean the total time to and from the main mode, for instance access time to airport by car, taxi or public transport.

Waiting time is the time spent waiting for a public transport vehicle, normally counted as a half of the headway but especially on low frequency connections maybe cut to a certain maximum. (See concealed waiting time)

Transfer time (in some cases also *terminal time*) is the time used for transferring line or mode excluding waiting time.

Schedule delay time is the extra time due to unreliability of travel times (deviations from the expected travel time)

Concealed waiting time is the time between a person's desirable and the worthwhile leaving time e.g. at home or work place. This occurs only in connection with urban low frequency public transport and in inter-urban travel by public transport modes rail, bus, air and sea and more commonly in rural public transport. (Holmberg, 1977)

Search time for parking is the time spent looking for an empty parking space.

Time lost due to congestion and unreliability is the time spent in congested traffic situations or lost due to presumption or fear of congestion or other negative incidents.

Variable, out-of-pocket costs

Public transport fare is the cost of a single journey according to the ticketing system in use. The distribution of ticket types (one-way, return, season etc.) by purpose of journey should be used in calculating the cost of a single journey. Concessionary fares can also be taken into account, e.g. in person group division.

Fuel price is the price consumers pay for a litre of fuel including taxes.

Parking charge is the single payment for the parking at the trip destination or a share of a prepaid periodic payment for a parking place.

Congestion charging and road pricing, road and *bridge tolls and distance based tolls* are direct or prepaid costs for car and sometimes separately for car passengers as well. They are similar to public transport fares and are treated accordingly.

Costs that are partly variable, partly fixed (the variable part consists of such costs that are related to the amount of travel and the fixed part is the cost the user has to pay regardless of use)

Vehicle investment cost is the capital cost of a vehicle including tax (the variable part should be allocated to a unit element of a trip, e.g. kilometre).

Vehicle maintenance costs consist of all other costs of having and using a vehicle such as costs of regular service, spare parts and repair, tyres, garage etc. (the variable part should be allocated to a unit element of a trip, e.g. kilometre).

Vehicle taxes, fees and insurance are additional charges imposed on the vehicle (usually independently of use and thus fixed costs). (If there exists a variable part it should be allocated to a unit element of a trip e.g. kilometre.)

Other costs

Subsidies, compensation in this context is an amount of money paid directly to the user for some special reason (e.g. disability or age) and should be counted per trip or per kilometre travelled.

Information provision, quality, level of service (other than frequency which is related to waiting time), security and user friendliness of the system have an effect on the generalised cost of a journey but are not generally considered as stand-alone components of the generalised cost but more like reinforcement or lessening to the effect of another component. The reason for this is that it is very hard to set a separate overall value for each of the effects and thus the valuation is incorporated in the value of the corresponding time component of the mode concerned. In practice, this means that people are willing to pay for quality, comfort, security etc. but the value is so case specific that it commonly is included in the values of time in the specific circumstances.

Especially in SPECTRUM and other projects that study effects of transport policy measures the use of person group based valuation compared to only mode specific valuation is essential because the effects comprises shifts from one mode to another and other changes in mobility behaviour within a person group. Thus, in the evaluation different user groups and different trip purposes should be looked separately if possible.

In state-of-the-art transport model systems the user generally can determine which items (of all the components the model can handle) are needed as output. Sometimes, however, some groups or factors are aggregated in such a way that they cannot be decomposed. It may also be that some components needed for the assessment (CBA or MCA) have to be calculated using model output as input for additional calculations.

It is recommended to use national monetary values for generalised cost components if available. Especially the value of time is very sensitive and needs a lot of care. The following in-vehicle time values based on average hourly wage rate show general relations between different travel purposes and contexts:

- Business: 100% of wage rate plus employer's contribution (100% employer payment);
- Urban commuter: around 50% of wage rate;
- Urban other private: 30-40% of wage rate (in general commuting trips should be valued around 15-25% higher than other private trips);
- Inter-urban commuter: 50-80% of wage rate;
- Inter-urban other private: 35-45% of wage rate.

If no national data is available the values introduced in UNITE and MC-ICAM projects with national correction can be used.

In addition, all studies show that other components of travel time related to a mode, such as auxiliary travel, wait and transfer times, are valued more highly than the in-vehicle time, around 1.5-2.5 times as valuable as in-vehicle time. The variations in the values seem to relate to the supply factors, e.g. comfort of transfer, surroundings for waiting and information provision. Therefore, if local studies of valuation are available, these values should be used.

The value of in-vehicle time increases with distance, with a larger increase for the car mode. Walk and wait time values do not increase as strongly with distance whilst headway becomes less important as distance increases.

Travel times in congested situation (peak hour, bottlenecks) should be valued around 1.5 times that of uncongested travel time for private trips and 1.1-1.2 times for business trips.

In practice it is sometimes more convenient to use distance based values in the evaluation procedure. Using suitable average or default values for speed these values can be derived from the known values of time.

The variable costs for the user are entirely location and study specific and the fixed costs usually country specific.

Efficient production of the transport system, infrastructure and services is a traditional part of the transport CBA. However, one should be aware of the risk of double counting. Special care is also needed when taxes and subsidies are treated. Even though they are transfers from one sector to another and therefore may not be seen in net calculations, their impact on individual sectors is crucial. Local organisational and legal circumstances have to be understood in order to correctly appraise the efficiency of transport service production. In CBA discounting rates between 4 and 6 % are recommended in most cases. For public funds a shadow price multiplier of around 1.25 is often applicable.

9.1.3 Conclusions for freight case studies

The surplus of producers of freight services may be complex to calculate, as there are many levels of operators involved, and often the benefit cannot be extracted from the transport models. It is useful to decompose the money flows and identify the roles of different actors.

Evaluation of impacts of policy measures on freight transport sector should be done with appropriate spatial dimension and by different industrial branches and by suitable commodity groups. Demand and supply should be modelled with capacity constraints in mind and using a multi-modal system description. In order to trace the full impact of policy measures aimed at the freight transport sector one should not only consider the direct effects within the sector, but also the indirect effects in and outside the sector. This is only possible if freight and passenger transport are integrated and their interactions with the rest of the economy are also taken into account. This leads to large scale models generally only used for evaluation of large packages of policy measures.

Carrying out CBA for the freight transport involves same rules and caution than stated for the passenger transport above.

9.1.4 Conclusions on equity

The trade-off between economic efficiency and equity is central to decision-making. Whether the introduction of efficient transport policies leads to an increase in inequality is an empirical question that needs to be addressed by designing and applying equity indicators. In fact, if a measure has any spatial effects there lies always the question of equal distributions of the impacts. Besides measuring spatial equity, accessibility is an important variable and measure of quality in the provision of transport infrastructure and services.

In appraisal work it is quite important to determine as clearly as possible what the equity concerns are; to identify the population, or segments of population who are concerned with a particular aspect of equity; the dimension along which equity is important for that particular population or segments of population. We also need norms and principles for the evaluation of the impacts of a policy on equity. These tasks require close cooperation and consultation with decision-makers and stakeholders. The technical issues related to the choice of a particular welfare function, an inequality measure, a poverty measure or an accessibility measure follows rather easily, once decision-makers and stakeholders have decided on the aspects of equity that they are concerned with and the norms that are needed to use for their evaluation.

Examples of intra-generational equity concerns are:

- Comparison of the welfares of the affected population before and after the implementation of the package. By choosing a welfare function we need to use an inequality aversion parameter that would reflect the decision-makers' trade-off between efficiency and equity. Since there is no guarantee that there would be a consensus among the decision-makers on the "trade-off", we probably need to show the results for different inequality aversion parameters. The same concerns apply to the use of an inequality measure. Any of the inequality measures have a normative content. Furthermore, if the choice of the inequality measure involves a decision about the inequality aversion parameter, that choice should also coincide with the decision-makers' trade-off between equity and efficiency.
- Evaluation of the changes in welfare into within and between segments of population, such as gender or different locations of the study area. In this case we need to apply a decomposable measure.
- Equity concern might be related to how the net-benefits of the package differ among different segments of a population or over different locations in the study area. Note that in this case, net-benefits could be negative, so the measure should be able to handle this.

- The equity concern can be related to the changes in the distribution of emission of pollutants over the area of study. One issue is to evaluate the changes into within and between segments of the population. The segments can be defined by the socio-economic characteristics of the population or by locations in the study area. Another issue is related to the evaluation of the extent to which a part of the population is exposed to an unacceptable ambient level.
- The equity concern can be related to the changes in accessibility of different locations within the study area. These concerns can be formulated in terms of the provision of a minimum acceptable transport services for all or for a specific segment of population or regions. In this case equity should be evaluated along the dimension of accessibility. By choosing an appropriate accessibility measure we can calculate the changes in distribution of accessibility over a region. The most important task is to make a decision about the "poverty line" or the minimum acceptable accessibility. Once this is defined, it is possible to apply the poverty measures to evaluate the number and the extent of the shortfall of accessibility in regions of the area.

For addressing inter-generational equity concerns we suggest to either use a lower discount rate for addressing the interests of distant generations or to use Minken's approach to weigh welfare between current and future generations (Minken et al. 2003).

Applying and computing equity measures in a transport context is novel. The SPECTRUM case studies will have an experimental character in this respect. We think it is important to concentrate on simple issues that are explored in depth rather than output a lot of unanalysed data. Consultations with decision-makers and stakeholders on the interpretability and usefulness of the measures will be vital.

9.2 Potential and actual barriers within the case studies

9.2.1 General comments on inter-urban case studies

General remarks

Common for the inter-urban case studies is the focus on impact assessment within a welfare economics based approach with focus on the following key elements:

- Consumers' surplus
- Producers' surplus
- External costs

As to the impacts that cannot be monetised and included in the CBA these impacts will be considered, as far as, possible within an MCA and/or descriptive analysis (e.g. based on expert opinions).

Some of the indicators outlined in Tables 2.1 and 2.2 may be difficult to take into account in the inter-urban case studies. The limited possibility concerns indicators regarding

1) Efficiency in the rest of the economy (for the efficiency objective),
2) Environment and Health (for the equity objective with respect to biodiversity),
3) Safety and security (for the equity objective with respect to vulnerable road users),
4) Liveability (for the equity objective with respect to vulnerable road users).

As part of the outputs of the models information about the following indicators will be provided in the scope of each specific study:

- Total person-kilometres / tonne-kilometres
- Total vehicle-kilometres (in person car equivalents) / tonne-kilometres
- Changes in modal split

In some studies it might be possible to provide indications about changes concerning CO_2 emissions on the basis of the data available.

Impacts on passengers

The guidance on impacts on passengers (Chapter 3) fits within the welfare economics based approach of the inter-urban passenger case studies. For the local uni-modal case studies (WP6) the intention is to use recommended values of time from the relevant country, ideally values which are specific to the mode being examined (this is in contrast to the recommendations, but should not be of importance given that only one mode is being examined). In the rail case study for example the time values recommended in the Passenger Demand Forecasting Handbook (PDFH) will be used.

As to the multi-modal case studies (WP7) it does become important to address the issue of values of time for different modes. As the analysis in those case studies will be structured to provide forecasts of demand by market segment (user group, travel purpose) it should in principle be possible to use differentiated values of times. However, this will require availability of time values for the different categories.

The principle of differentiating values of time for user groups and travel purpose (business, commuting and leisure) is satisfactory. However, demand data in practice may only allow differentiating according to travel purpose and not according to different user groups.

For the inter-urban case studies some of the travel time components may be less important or data not sufficiently available. In these cases in-vehicle travel time will dominate the analysis.

The recommendation that variable costs for the user are mainly location specific and the fixed costs usually country specific is realistic (although it needs to be verified in the case studies).

Impacts on freight

The outlined framework for examining impacts on freight will be sufficient for the freight case studies. Further details of the freight studies are given below in the section concerning the case study for the port of Antwerp.

Impact on transport system performance

The case studies should consider impacts on transport system performance. Where relevant changes in investment and land take costs (relevant particular for physical measures), operation and maintenance, government revenue and producer surplus will be assessed in the case study analysis. Consideration will be given to issues concerning discounting and shadow costs of public funds on the basis of the guidance given in this deliverable.

Measuring impacts on safety and accidents

Impacts on accidents will be assessed in the case studies. The suggested guidance is particular relevant for the road case study and the multi-modal case studies and less relevant for the rail, sea and air case studies (due to the low accident levels for these modes). For the rail case study, it may be possible to consider impacts on road if it is possible to estimate modal shift effects. However, data problems may limit calculation of these impacts. In Chapter 6 it is mentioned that the value to friends and relatives should be ignored. In uni-modal studies it may also be a problem to get data for other modes than the one being examined. This issue should not be a problem in the multi-modal case studies.

Measurement and treatment of externalities

The recommendation concerning use of country-specific or region-specific values for monetising externalities is appropriate for the inter-urban case studies. If such values are not available in the country or are not applicable alternative European values will be used (e.g. the ones used in the UNITE project). As far as it is possible we will include impacts in terms of congestion costs, scarcity costs, local air pollution and noise. These impacts may be determined on the basis of the forecasted demand changes together with information about unit costs for each externality group (e.g. emission costs per passenger kilometre or tonne kilometre). It may be very difficult to include impacts with respect to other externalities such as visual intrusion and other physical externalities as highlighted in Chapter 7.

Measurement and treatment of equity

It would be rather difficult to look at equity impacts within the inter-urban case studies due to lack of data concerning profile of users and other affected groups (with the exception of the Norwegian case study, see below). The proposed procedure for the rail case study may be applicable for other of the inter-urban case studies as well. That is to look at how different travel groups are affected by a given instrument in terms of welfare (e.g. welfare effects categorised by ticket type). This could possibly be extended to other types of categorisations of users and/or different locations in the study area. Furthermore, it may also be possible to include information about changes in accessibility of different locations within the study area, e.g. based on a gravity type of approach or travel cost approach as outlined in Sections 8.7.1 and 8.7.2.

Economic development

Although important wider economic impacts may be generated from various transport policy instruments it may be rather difficult to at least quantify such effects. A starting point could perhaps be to examine market structures in the transport using sectors to identify whether imperfect competition appears to be present. If imperfect competition is present then a traditional transport CBA would underestimate the net-benefits of a transport policy intervention. This may though be outside the scope of the work in SPECTRUM. A more descriptive analysis based on expert opinion may be required, e.g. to highlight whether the instrument (e.g. a transport infrastructure scheme) is mainly influencing an area with above average unemployment/ below average income levels to highlight the case for economic regeneration.

9.2.2 General comments on urban case studies

General remarks

The urban case studies focus on the evaluation of alternative packages of instruments for the achievements of the high level objectives of SPECTRUM (fully outlined in D5 and listed here in Table 2.1). These evaluations will be within the theoretical framework outlined in D4. The evaluation of the interactions (substitution, synergy and complementarity) between economic instruments and physical and/or regulatory instruments is another aim of these case studies.

Although all the objectives are relevant, none of the urban case studies will be able to evaluate all the sub-objectives formulated in SPECTRUM (see Table 2.1). This is partly due to the limitations of the model systems. The models are partial equilibrium models that focus on the interactions within the transport market or transport and land use but do not take account of the interactions between the transport market and the rest of the economy. Hence we are not able to address those sub-objectives that are related to the labour market or regional growth. Furthermore, due to the specific limitations of variables in each model system it is impossible to address a number of other sub-objectives such as liveability, security, reduction of fragmentation and promotion of biodiversity. Finally, the model systems are not able to address all possible segments in the population.

The available outcomes of the models are compatible with the suggested assessment framework and thus the results can be presented according to the suggested formats (see Table 2.3 and Table 2.4). Depending on the case study all relevant information on common indicators such as total person-kilometres, total vehicle-kilometres, change in modal split, total emissions of pollutants, total number of accidents by category, etc. will be provided.

Impacts on passengers

The urban case studies will follow the guidance provided for impacts on passengers (Chapter 3). Since the variables included in the generalised cost of a trip in the models are prespecified, there are a number of items that the models may not be able to address, for example schedule delay, reliability, search time for parking, information provision, quality and level of service.

Regarding segmentation, the ability of the models used in the urban case studies varies as well. Depending on the model and the data available the effects of a policy related to income, age and gender can be calculated.

For the evaluation of the travel time-savings the national values will be used. In some models these values are readily used as the implicit values of the model. The capability of the model systems to differentiate the impacts by travel purpose, user groups, etc. differs. When such capability exists, it is also possible to differentiate between the values of time. Since all urban case studies are multi-modal, differentiating between values of time by mode is also possible, and will be used if proper grounds exist. Differentiating between peak and off-peak conditions may also be appropriate.

Impact on transport system performance

The urban case studies will address impacts on transport system performance according to the suggested guidance (see Chapter 5).

Measuring impacts on safety and accidents

All urban case studies will measure the impacts on safety and accidents using the recommended method and national values when available.

Measurement and treatment of externalities

The urban case studies will follow the recommendations concerning the measurement and treatment of externalities. Since most of the externalities are local, local or national values will be adopted for valuations (except for CO_2). Impacts in terms of congestion costs, scarcity costs, local air pollution and CO_2 will at least be included. Due to lack of sufficient data impacts related to noise are difficult to evaluate in all the case studies. Also other impacts such as those related to visual intrusion or "physical externalities" are difficult to address due to lack of relevant data and practical methods.

Measurement and treatment of equity

Since all the urban models have spatial dimension, it is possible to calculate the distribution of the impacts over a geographical area. This will allow all the urban case studies to address equity concerns over the study area. However, different models have different capabilities in addressing the impacts of a policy by different segmentation type (income, age, gender and household type). When it is possible to calculate the impacts for different population segments, also measures of equity can be successfully applied. Some urban case studies can also calculate different measures of accessibility and evaluate the effects of a policy using these indicators.

Economic development

The models applied to the urban case studies do not allow themselves for the evaluation of economic development impacts associated with a given policy instrument.

9.2.3 Specific comments of the case studies

Norwegian case studies

The Norwegian case studies are both passenger transport studies, the Oslo case study being an urban study and the so called Norwegian case study inter-urban.

The Oslo case study focuses on passenger transport in the Oslo region. In general, the RETRO/FREDRIK model system used in this case study cannot address a number of sub-objectives. This is partly due to the limitation of the model type, a partial equilibrium model system that focuses on the interactions of transport and land use, to address other markets in the economy, such as labour market or regional growth. Furthermore, due to the limitations of variables in the model system it is not possible to address a number of other sub-objectives. Examples of these sub-objectives are those related to liveability, security, reduction of fragmentation and promotion of biodiversity. Finally, the model system is not able to address all of the possible segments in the population such as vulnerable transport system users.

The national case study focuses on passenger transport at a national level in Norway. The National Transport Model used in the study is a partial equilibrium model that focuses only on the transport market. Limitations of the model system in addressing sub-objectives are similar to RETRO/FREDRIK.

The variables that are included in the generalised cost of a trip are limited. For instance schedule delay, reliability, search time for parking, information provision, quality and level of service cannot be addressed. The fixed car costs are not considered as a part of the generalised cost of a trip. The fixed car costs affect car ownership that in turn influences the mode choice. The types of segmentations that these models can calculate are the effects of a policy related to income, age and gender. For values of time the implicit values in the models and the Norwegian national values will be used.

For measuring impacts on safety and accidents the recommended method and national values will be used. For congestion the nationally recommended volume delay functions will be used thus affecting the travel time, but there will be no differentiation in values of time for congested and un-congested periods. Noise is not possible to address since sufficient data on the location of population in relation to the transport networks are not available. Calculation of emissions of pollutants and CO_2 as well as monetising the impacts is a common practice already adopted in the models and the appraisal method. Visual intrusion or "physical externalities" cannot be addressed for the same reason as noise, necessary data for the calculations are lacking.

Due to the characteristics of the Norwegian models the impacts of a policy for different segmentation types (income, age, gender and household type) can be addressed even at a fairly detailed zonal level. Measurement of equity can be performed in detail; it is even possible to construct different measures of equity. Also different measures of accessibility can be calculated and thus the effects of a policy in these measures can be evaluated.

The Madrid Airport case study

In the Madrid Airport case study the following instruments will be considered:

Regulatory instruments:
1. Slot allocation

Economic instruments:
2. Slot pricing
3. Marginal social cost pricing (noise problem)

Physical instruments:
4. New infrastructure

The case study will focus on:

1. The impact of *new infrastructure* since the airport is undertaking a huge expansion at the moment
2. The problem of noise that is closely related to the impacts of expansion.

For the impact of new infrastructure (1.) the demand at the airport needs to be estimated which leads to the problem of scarcity and allocation of capacity. At this point some estimates of demand elasticities at airports will be needed. However, this subject has been treated in the literature only marginally as most studies deal with airlines' demand elasticities, but barely with airport demand elasticities.

The problem of noise (2.) is easier as at airports noise is one of the main externalities, and has thus been treated in the literature quite extensively. However, the value of the airport noise is very case and location specific as it depends on the size, location and surrounding land use of an airport. For this reason there is only general guidance on airport noise but no specific values can be given.

In airports, both Stated Preference (SP) and Revealed Preference (RP) methods have been employed to estimate the economic value of reductions and increases in noise levels. The majority of valuation studies on noise are Hedonic Price studies. These studies provide values in terms of the Noise Sensitivity Depreciation Index (NSDI), which is the percentage change in house prices per decibel increase in noise level. In the Madrid airport case study different values of NSDI will be used in order to perform sensitivity analysis.

Given limitations concerning data access only some general conclusion about impacts on users' surplus, which for the airport case might be either airlines or passengers (as the final users of the airport), can be reached.

The East Coast Mainline

The rail case study is based on the East Coast Mainline where the PRAISE model will be used for the analysis (see e.g. Preston et al., 1999).

The model uses the following inputs:

- Demand figures; i.e. travellers on each OD pair (origin-destination pair)
- Fares; for each ticket type and operator
- Market shares: the model is calibrated using base market shares
- Costs; fixed and variable costs for each train operator
- Elasticities of demand; by OD pair and ticket type
- Values of time and adjustment time[44]; taken from the Passenger Demand Forecasting Handbook (PDFH)

The base is calibrated using a sample of individuals drawn from a departure time profile that is relevant to the particular OD pair and ticket type. Thus the only difference in the individuals comes from their desired departure times.

An aggregate value of time for each OD pair is calculated based on a market share weighted sum of values of time for all modes, as shown in the PDFH. Model market shares are a function of distance and correspond with figures given in the PDFH. The rail values of time are a weighted average of commuter, business and leisure.

Scenarios can be generated based on changes in fares and service provision. The following output is produced:

- Forecast demand by market segment
- Operator Revenue and Costs
- User Benefit (Consumer surplus)
- Overall change in welfare (excluding equity effects)

This case study is aimed at specifically examining the issue of scarcity on rail and the mix of pricing/ regulation as ways of addressing them. Subsidies and auctioning of slots and combinations of the two are going to be looked at to get some idea of how to make the best use of scarce capacity on the ECML. It might also be possible to look at impact of investment to increase capacity.

Yet, it cannot be stated how far we can get addressing the new issues, particularly the equity ones, covered in this deliverable. Some of the issues mentioned are rather irrelevant to this case study, such as safety of vulnerable users (as this is an inter-urban rail study). Some other issues will be hard to measure because PRAISE is a partial equilibrium model, so, for example, the effects of rail policies to other parts of the economy are not linked, or the impact on the income distribution will not be looked at.

[44] Adjustment time is the difference between the most desirable departure time and the actual timetabled departure time, sometimes also called concealed waiting time.

These issues are highlighted in more detail in the text below. Referring to Table 2.1 in relation to what can be done (and what cannot) in the rail case study:

1. Economic Efficiency

- PRAISE is set up to provide measures of changes in *economic efficiency*. In PRAISE, Generalised Cost is a function of journey and wait time components, with just one aggregate value of time per OD pair (as described above) and the fare of the journey. (No other costs are included in PRAISE, e.g. parking fees are not considered.) PRAISE is not set up to deal with reliability, quality, security or information provision.

- Since PRAISE is a partial equilibrium model (excluding some indirect effects on the economy) *efficiency in the rest of the economy* cannot be measured. However, it is assumed that the indirect effects are going to be extremely small for the case study as it is not focusing on huge investment programmes, but essentially aimed at utilising existing capacity in the best way, by finding ways of getting the most efficient usage of the available slots.

- Regarding *environment and health* PRAISE provides figures on modal shifts. These could be utilised to impute environmental effects by applying changes in vehicle-kilometres for different modes to UK specific figures (from Surface Transport Costs and Charges (SCTT)) and for comparison to values suggested in UNITE. Impacts on biodiversity are hardly possible to evaluate. Effects on land take, urban sprawl, health benefits from physical activity, protection of valuable areas are going to negligible.

- For *safety* changes in accident costs can be looked at, but *security* hardly seems relevant.

- The impact of the proposed analysis on *economic development* will be extremely small, and could be handled better by general equilibrium models (PRAISE is a partial equilibrium model).

2. Equity

- Regarding *equity*, the travellers can be divided up into three groups:
    - Regional (local non-London stopping services)
    - London regional services
    - Intercity services (to/from London)

- Potentially, it could be possible to divide up the results from the case study, by grouping the OD pairs into these three categories. Because the values of time used in PRAISE vary by distance (and not by journey purpose), these groups will have different values of time, and so will values of generalised journey time change differently. It might also be possible to try to ascertain an average *income measure* for the 3 groups and create some weightings based on these. However, it is uncertain whether the tested measures will actually change the income distribution though, and even if it did how the changes could be imputed. If there will be resources left this will be looked at.

- With regard to *segregation*, if something about the average incomes of different travel groups can be said, it might be possible to say something about the changes in trip rates for these groups as well and how this may have changed segregation by income. It is difficult to see what could be done on spatial equity.

- With regard to *accessibility* issues, a comprehensive study of a particular area with all modes considered would be needed to really look at these. Just looking at a rail line it is difficult to see how these changes could be assessed.

UK urban case studies

The text below covers specific issues concerned with the two UK urban case studies: York and Leeds. Given that the urban case studies are at the present still at an early stage and are thus not so well-defined, some further information to the general comments about urban case studies given above can be supplied.

The York Case Study will concentrate particularly upon packages involving parking measures and will use the SATURN model to test these packages. The Leeds Case Study will use both the MARS model and SATURN to test packages that are currently being defined. These packages will be analogous to those being tested in the Oslo Case Study. MARS and SATURN model features have been summarised in the SPECTRUM Inception Report (Deliverable 1), though MARS was referred to under its previous name of SPM.

A. York Case Study

As stated above, the York Case Study will mainly be concerned with packages including parking measures and will use the SATURN model to test them. These packages will be of a type that only have a small effect on mode-switching and on other demand responses, i.e. their main impact will be on route-switching and car-park switching (including use of “park-and-ride”). Efforts will be made to investigate whether the York SATURN model can be adapted to take into account parking search time.

It is not known at this point whether local data exists to support calculating values of time from local wage rates, as is recommended. A decision will need to be taken later within the case study, which values should be used and which segmentation is possible and relevant.

B. Leeds Case Study

When constructing the Leeds MARS model the following sources of information have been used:

- Neighbourhood statistics
- Bristow A. et al, Obtaining Best Value for Public Subsidy for the Bus Industry: LEK Research, Appendix 9: Results of Route Level Models (ITS/TSU)
- National Travel Survey Update 1998/2000

- Leeds Economy Handbook 2002
- Leeds Unitary Development Plan
- Leeds Local Transport Plan and Monitoring reports
- FATIMA-project
- TEMPRO

It is likely that these sources of information will contain wage rates (though this will need to be checked) if it is decided to adopt the UNITE/MCI-CAM approach in the urban case studies. Furthermore, this information could be used to provide segmentation for the Leeds MARS model, though this issue will need to be examined more closely.

The Leeds SATURN model will clearly need to use values of time consistent with the MARS model. As with the MARS model, it is possible that the information listed above could be used to provide segmentation to the Leeds SATURN model.

C. Other comments

MARS and SATURN do not model freight traffic as a general sector. However, SATURN does distinguish in its assignment model between different user classes and so can take into account the specific route-switching impacts associated with HGVs as distinct from other vehicles.

Issues concerned with transport system performance, the impacts on safety and accidents, externalities and economic development for the York and Leeds case studies are the same as described in the general comments on urban case studies.

With respect to equity, it has already been pointed out above that there is the possibility of providing segmentation in the Leeds MARS and SATURN models. This segmentation could be used to provide measures of equity based upon other criteria than that of residential location.

Port of Antwerp

There is no ready-made model for analysing in a systematic way all impacts on port operations of changes in relevant variables. Only for some specific relations between variables, a number of coefficients can be presented in a spreadsheet format. It should be kept in mind that these are completely case-specific.

As sea transport's share in *passenger transport* is extremely small, the value of time observations made in the passenger part (Chapter 3) are of limited use. Passenger transport by sea consists of (regular) ferry services and (chartered) cruise services. In Antwerp, no ferry services are calling. Cruise ships on the contrary are users of the Port of Antwerp, but since we are dealing with a very specific kind of leisure travel, very specific variables are involved which go beyond the SPECTRUM scope.

From *the freight analysis* in Chapter 4, as indicated, use will be made of available elasticities, although the number of indices retained from literature is very limited and very case-specific. On the other hand, it is sometimes hard to reproduce the same variables for other cases since a large number of determinants may not be easy to quantify. The methodology of Section 4.2.4 is indeed applicable, be it with the quantitative restriction that for the Iron Rhine corridor e.g., the part falling outside Belgium and the Netherlands, requires an extension to the MOBILEC model to incorporate the German situation, which again goes beyond the SPECTRUM scope.

For the specific impact of *accidents*, values in Chapter 6 are focussing on persons and not on commodities. The cost of accidents on commodities is a typical component that needs to be included in the port case study. As to the *externalities*, some can be included in the port case study without too many complications (e.g. congestion), whereas others cause more methodological and data problems (for noise, pollution, visual intrusion and physical externalities, the port's share is under large discussion as far as externality levels are concerned).

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MC-ICAM (Marginal Cost pricing in transport – Integrated Conceptual and Applied Model analysis)
http://www.strafica.fi/mcicam

OPTIMA (Optimisation of Policies for Transport Integration in Metropolitan Areas)
http://www.its.leeds.ac.uk/projects/optima/index.html.

PROSPECTS (Procedures for Recommending Optimal Sustainable Planning of European City Transport Systems)
http://www-ivv.tuwien.ac.at/projects/prospects.html

SPECTRUM (Study of Policies regarding Economic instruments Complementing Transport Regulation and the Undertaking of physical Measures)
http://www.its.leeds.ac.uk/projects/spectrum

TRANSPLUS (Transport Planning Land Use and Sustainability)
http://www.isis-it.com/transplus/

UNITE (UNIfication of accounts and marginal costs for Transport Efficiency)
http://www.its.leeds.ac.uk/projects/unite/index.html

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