DIFFERENT

User Reaction and Efficient Differentiation of Charges and Tolls

DELIVERABLE D2.1

CURRENT STATUS OF DIFFERENTIATED CHARGES FOR TRANSPORT INFRASTRUCTURE USE

Due Date:	31 October 2006
Submitted:	30 November 2006
Main Author:	ISIS
Dissemination:	Public

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006), Priority 6.2 Sustainable Surface Transport

Contract number 019746

Project Start Date: 1 May 2006, Project Duration: 2 years

Document Control Sheet

Project Number:	019746		
Project Acronym:	DIFFERENT		
Workpackage:	Deliverable 2.1 Current Status of Differentiated Charges for Transport Infrastructure Use		
Version:	2.1		
Issue Dates:	Version 0.8	13/10/2006	Submitted to peer review and Advisory Board
	Version 1.0	30/11/2006	Submitted to European Commission, released to consortium and Advisory Board
	Version 2	17/1/2007	Released to Commission, consortium and Advisory Board
	Version 2.1	18/1/2007	Released to Commission, consortium and Advisory Board
	Version 3	30/3/2007	Released to Commission, consortium and Advisory Board

Classification

This report is:

Draft	
Final	X
Confidential	
Restricted	
Public	X

Partners Owning:	All
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EXECUTIVE SUMMARY

The objective of this deliverable is to provide a background analysis that allows the identification of the key issues that will be addressed in the subsequent DIFFERENT deliverables and work packages.

The deliverable focuses on the following research areas:

- the theoretical background of charges differentiation for infrastructure use as far as economic theory and behavioural theory are concerned,
- existing charges differentiation practices across European countries with reference to all transport modes (road, rail, maritime and airport infrastructure) and
- the availability of modelling tools that can be used to assess the potential impacts of differentiated charges.

Economic theory provides a complex picture. On the one hand, an analytical stream of economic theory suggests the optimal framework (the normative approach) for transport charges differentiation. It is reached pursuing economic efficiency, a concept derived from welfare economics, according to which transport charges (prices) should equate with marginal social costs in order to obtain the maximal social welfare. According to this theory, prices should be equal to marginal social cost (throughout the economy) to obtain maximum social welfare. With this pricing principle, potential travellers who value their trip above the costs they impose by adding to traffic flows will travel. Those who value their trip below that cost will not travel or use some alternative means. Such an optimal price is based on all costs involved with driving one additional kilometre, or one extra transport unit using infrastructure. Because this also includes external costs, these charges are highly differentiated and vary along with variations in many behavioural dimensions.

On the other hand, a complementary stream of analysis questions the practical application of the concept of marginal cost in transport, due to technological, institutional and political reasons, opening the way for deviations from the first-best pricing rules, i.e. towards second-best pricing approaches. This means a move from a normative approach (how transport charges should be in order to ensure welfare maximization) towards a positive approach (how transport charges actually may be when taking account of real-life constraints).

In terms of impacts on charges differentiations practice, it can be said that following the normative approach a high degree of charge differentiation is required, i.e. the charges should vary taking account of several dimensions simultaneously (variability of vehicle technology, time of travel, place of driving, driving style, etc). Conversely, following a positive approach, a less differentiated price structure could be required. Economic theory offers in fact several options that are second-best: optimal given the existing constraints. Most likely these pricing measures will be differentiated according to a fewer number of behavioural dimensions, reducing the complexity of the pricing structure.

Behavioural theory may suggest the adoption of a less differentiated charge structure also in consideration of the cognitive limitations that restrict the degree of complexity that people can deal with and thus the degree of differentiation possible. People in fact do not just react “rationally” to transport infrastructure charging. There are several constraints on behavioural adaptation to differentiated prices which can depend not only on cognitive but also motivational, personal or situational factors. The degree of differentiation implied by first–best pricing may prove to be too complex for people to deal with. The most important questions are:

- Up to which degree of complexity are people able and willing to understand and to respond to differentiated charging structures?
- Which are the relevant psychological factors that determine the relationship between price differentiation and user reaction?

A first theoretical approach assumes a non-linear relationship between the level of price differentiation and its effectiveness: there is a point, beyond which the price differentiation and therefore the effort involved into understanding a price system becomes too large, which will lead to a loss of its effectiveness, because people will avoid a system that has become too complex altogether and will stop trying to use it to their best advantage. So far, it appears that the cognitive capacities of individuals as well as their willingness to process complex information on highly differentiated pricing systems play an important role in limiting their potential effectiveness.

Within the DIFFERENT project this theoretical approach and the related questions shall be addressed by analysing theoretical and empirical knowledge concerning the identified psychological factors which may have an impact on user reaction towards differentiated pricing. This theoretical analysis shall lead to the formulation of hypotheses about peoples´ response to complex pricing systems. As there is very little empirical evidence, and since much of that which exists is controversial, it will be quite difficult to formulate clear hypotheses on every aspect. It is therefore necessary to prioritise research questions to be explored within the DIFFERENT project. The analysis of case studies and/or the implementation of small experiments will clearly be required to allow an empirical analysis of the theoretical approach.

Concerning the **existing charging structures**, differentiation criteria for road (urban and motorways), rail, air and maritime (ports and port access e.g. access channels) infrastructure use, the analysis allows the evaluation of two different but interwoven processes: a) the degree of convergence across European countries around specific charging practices and b) the degree of differentiation reached by each charging scheme.

The ‘degree of convergence’ looks at the level of current harmonization between existing charging practices across European countries.

The ‘degree of differentiation’ concerns the capability of existing charging differentiation schemes to address the variability of transport conditions, e.g. time, locations, traffic conditions, etc, in order to charge the users at the point of use of the infrastructure by taking account of the full range of externalities.

The following table summarises the current state of the two processes for each infrastructure type in terms of their qualitative assessment in high, medium and low levels.

		DEGREE OF DIFFERENTIATION		
		High	**Medium**	**Low**
DEGREE OF CONVERGENCE	**High**	Motorways		Airport
	Medium		Rail	
	Low	Maritime	Urban Roads	

Motorways and maritime infrastructure both show a high level of differentiation but lie on the opposite side of the classification in terms of convergence. Infrastructure charges for the use of **motorways** show a high degree of convergence across the European countries in so far as at least some part of the motorway network are charged in most European countries. The degree of differentiation is often very high: all of the most important parameters affecting externalities, e.g. type of vehicle, distance travelled, weight, emission class, etc, have been considered in the determination of the charge (even if they are then generally not been accounted for in full).

Charges for the use of **maritime infrastructure** also display a high level of differentiation, but at the same time the level of convergence is low. Charges are levied on the basis of a variety of principles and with a strong involvement of local, municipal or regional authorities.

The degree of differentiation and convergence in **rail infrastructure** charging occupies an intermediate position, in the sense that both processes are currently under way, with lights and shadows. Differentiated charges currently applied mainly consider infrastructure damage (gross t-km), type of train and distance travelled (train-km), which capture some of the important drivers addressing externalities. However, charges for congestion and scarcity are scarcely levied in rail track access charges in Europe. On the other hand, the process of convergence, even if not completely fulfilled, is being supported by the European Commission through the "Common Transport Policy" and specific Directives[1], aiming at ensuring interoperability and adopting common approaches in charging infrastructure at national level.

Urban roads and airport infrastructure charges show a mixed trend, i.e. a medium degree of differentiation with low convergence (urban roads) and a low degree of differentiation with high convergence (airport). Charge differentiation for the use of **urban roads** has been rising over the past years, i.e. from the charge for public transport and for parking space for deterring the use of urban space (the most common forms of charging) to more sophisticated charging schemes addressing congestion and environment. However, there is no convergence yet: charging with the specific aim of reducing congestion is only applied in very few cities (London, Stockholm), while most only charge for entering in a specific city area.

In **airports** there is a large convergence towards the use of landing charges for recovering the runway provision and maintenance, based on the maximum take-off weight, and, particularly in large airports near urban areas, a charge addressing noise and emissions. It should be noted, however, that noise is basically addressed with command and control measures and charging still only has a minor role. Even less important has been the role of emission charges so far. Nevertheless reduction of the climate change impact of aviation is coming top on the European Commission agenda now. The introduction of an Emission Trading System (ETS) and a tax on kerosene are the main regulatory instruments being considered at the moment. Even less examples can be found with reference to charging based on congestion and scarcity.

Concerning **future possible developments** of charge differentiation, it is widely acknowledged that technology is deemed to play an important role, providing the material basis for a sharp increase in charging differentiation. The future developments of positioning technologies, for example, including combinations of Dedicated Short-range Communication (DSRC) equipment and GPS/GSM approaches, are expected to allow further scope for charge variation. Highly sophisticated OBUs fitted with maps, GPS devices, cellular technologies for communication and back-office operations, could allow the capture of variations in traffic situation, road infrastructure use, population distribution, etc. GALILEO, the European satellite navigation system, has recently received a new push. All the relevant parameters for a full assessment of external costs and in particular for an effective pricing of congestion could be potentially addressed through the use such technologies.

It is to be expected that technological developments are pervasive and able to affect all transport modes in the same way. Currently GPS-GSM devices find their main application in the road sector, for instance in the German HGV tolling system that relies on satellite tracking to determine the distance trucks travel on the autobahn network, while in several countries car insurance premiums are becoming based on distance travelled (through in-vehicle GPS). However, also in the maritime sector more pollutant ships are being tracked at ports and along the trip in most environmental sensitive areas (Mediterranean Sea), and GPS devices are also used for real-time communications about rail delays in freight services.

There are a number of **modelling tools** available for the assessment of potential impacts of differentiated charges for transport infrastructures, although their degree of coverage of the various transport modes is definitely not homogenous. These modelling tools might be divided into two main categories: multimodal models, which are capable of dealing with several transport modes at the same time and of looking at the long-term consequences also in terms of modal change, and mode specific models, which might offer an in-depth analysis of the characteristics of a given transport mode. In the first group, the level of analysis is usually of strategic nature and covers metropolitan areas, regions, countries and in some cases the whole of Europe. Among the transport modes, road transport is much more analysed than any of the other modes and this would make it possible to analyse the impact of some types of fare differentiation. Furthermore, there are distinct differences between models available for the passenger and the freight sector:

[1] Directive 91/440, Directives 2001/12, 2001/13 and 2001/14

- In the ***passenger sector***, most of the models in use assume that individual consumers (travellers) have full and perfect knowledge of prices and respond to them wholly rationally". Such models do not allow for the fact that consumers might not be able or willing to understand complex price structures nor be equipped to responds to them wholly rationally.
- In the passenger sector the behaviours of the suppliers who set prices and of the consumers who pay them are rarely considered within a single model; the usual situation is for the behaviour of suppliers to be represented extremely simplistically – and indeed often only by means of exogenous assumptions.
- Among the potential responses of individual travellers to differentiated charges, only route choice and mode choice are modelled in much detail. Models tend to ignore, or deal rather simplistically with other potential responses such as change in driving style, departure time, destination or trip frequency. Longer term responses such as changes in car ownership, activity patterns or residential location are dealt with briefly if at all.
- The variation in behaviour in response to changes in prices over time is not generally dealt with in much detail. Most models tend to assume the existence of an equilibrium between supply and demand and do not dwell on the dynamic processes by which this might come about or the dynamic disequilibria which might exist. Similarly, most traffic models are concerned with a particular time of day (e.g. the peak or off-peak) and do not seek accurately to represent the transition between them.
- In the ***freight sector***, the models used to predict organisations' response to prices are quite simple and tend either to assume that decisions will be made in such a way as to take full account of any price differentiation or variation (almost irrespective of any administrative costs involved in so) or that they respond to medium term average costs without regard to differentiation or variation. There is insufficient data and knowledge to know where, on the spectrum between these responses, the response of a given firm might lie in a given circumstance.
- Most of the models used to predict the performance of transport systems are focused on demand behaviour and derived from engineering and statistical analysis. The models of the road sector tend to be the most advanced. Tools to investigate tariff differentiation in the rail, air and shipping sectors come mainly from the economic analysis and although quantitative, are not models in the sense that the term is used in the road sector.

In brief, the quantitative assessment of the effect of the differentiation of charges has to take into account the features of currently available modelling tools, which only partially cover the several dimensions involved in this topic.

1 INTRODUCTION

The DIFFERENT Deliverable 2.1 focuses on four research areas:

1. to review the body of economic theory of differentiated charges for infrastructure use (chapter 2);
2. to introduce concepts and approaches of the behavioural theory in response to differentiated charges (chapter 3);
3. to review at European level the implementation of differentiated charges for infrastructure use, shedding light on criteria, degrees of differentiation and convergence (chapter 4);
4. to review the characteristics and field of applications of existing transport models, in particular analysing their capability to simulate the impacts on transport demand and users' behaviour in presence of differentiated charges (chapter 5).

The aim of the analysis is to provide a background analysis allowing the identification of the key issues for each area that will be addressed in the subsequent DIFFERENT deliverables and workpackages. Hence, the analysis has been designed to set the scene for the future DIFFERENT research and not to provide an exhaustive analysis of all the theoretical and practical implications arising from the economic, behavioural and modelling tools analysis of differentiated charges for infrastructure use. References can be found in the final section of this deliverable for further details about authors and issues.

Chapter 2 deals with the economic theory of differentiated charges for infrastructure use. It distinguishes two different approaches: the normative and positive economic theory of price differentiation. The normative approach in discussed in the section 2.2 in two sub-sections: 2.2.1 about efficient pricing and the implications this may have for differentiation of transport prices, and 2.2.2 which addresses important complexities that arise from the nature of the cost structure of the transport industry, and other relevant pricing constraints. The positive theory of regulation and its consequences for price differentiation are discussed in sub-section 2.2.3. Finally, Section 2.3 draws some conclusions.

Chapter 3 introduces the behavioural theory. Following a general introduction to this chapter, sub-section 3.2.1 focuses on psychological theories of behavioural adaptation and on those psychological constraints which are seen as most relevant. Sub-section 3.2.2 concentrates on empirical evidence that is so far available from other studies and past research concerning traffic user reaction on differentiated prices, but also includes transferable results from other sectors such as telecommunications. The last section 3.3 draws conclusions and provides an outlook for further analysis within DIFFERENT.

Chapter 4 reviews the on-going practice in charging of infrastructure use. For each type of infrastructure, basic issues like charge description, level of implementation, institutional background, underlying principles, etc are discussed. The chapter then draws conclusions about trends, patterns and future development. A particular issue is the assessment of current degrees of differentiation and convergence and possible developments driven by technologies. This task partially overlaps with GRACE, an on-going DGTREN research project on generalization and research on accounts and cost estimation; the main difference is that GRACE aims at finding new evidence on charge differentiation through specific case studies in a sample of EC countries, while DIFFERENT provides an overview of the current implementation of charges at EU level.

Chapter 5 reviews the existing models for the impact assessment of the application of differentiated charges. More specifically, the chapter presents: a) generalities on modelling approaches (on a mode by mode basis); b) examples of applications of modelling approaches (on a mode by mode basis); and c) a discussion of the capability of the modelling applications presented to simulate differentiation of tariffs.

Final conclusions are drawn in chapter 6.

2 ECONOMIC THEORY

2.1 INTRODUCTION

Transport has some characteristics that make it different from other goods. Possibly the most important characteristic of transport is that it is often not really demanded in its own right (Button, 1993). People wish, in general, to travel so that some benefit can be obtained at the final destination. Similarly, users of freight transport perceive transport as a cost in their overall production function and seek to minimise it wherever possible.

While the demand for transport has particular, if not unique, features, also certain aspects of supply are entirely peculiar to transport. More specifically part of the plant is mobile - almost by definition – and is entirely different in its characteristics to the fixed plant (for example, roads, airports etc.). The fixed component is usually extremely long-lived and expensive to replace. Further, few pieces of transport infrastructure have alternative uses.

Demand and supply work together to determine the market price in competitive markets. The price of a good or a service is what must be given in exchange for the good or service (Stiglitz and Driffill, 2000). When the forces of supply and demand operate freely, price measures scarcity. In addition, in the competitive model, the equilibrium price of an object will normally equal its cost of production (including the amount needed to pay a firm's owner to stay in business rather than seek some other form of employment). Elementary economics tells us that in the long run price will then be equated with the marginal (and average) costs of each supplier. But the transport market is different. Simple market economic theory cannot directly be applied to transport for a variety of reasons. Since journeys are unique in space and time, monopoly is likely to arise in varying degrees, especially when technological change offers an advantage to a particular mode or where economies of scale affect one mode more than another. This situation also affects the pricing of transport services. Transport prices do not simply result from the law of supply and demand.

The complexity underlying transport pricing arises if one looks at the different transport pricing objectives.

Pricing can be seen as a method to affect resource allocation. Pricing strategies permit specified aims to be achieved; there is no such thing as the right price independent of the aims pursued. The pricing policy adopted by any transport undertaking with some degree of market power depends upon its basic objectives. For example, an optimal price aimed at achieving profit maximisation may differ from that needed to maximise social welfare, or to ensure highest sales revenue. Social welfare refers to the measure used to express a society's aggregate well-being. It can be defined in many ways, most of which take individuals' utilities as a building block. Applied research often uses (weighted) sums of individual welfare measures, which is true also for "social surplus" as we will use below. There is no objective criterion for the specification of a social welfare function; i.e. economists can not define it objectively (see, for example, Atkinson and Stiglitz (1980) for further details).

In some cases there is no attempt to devise a price to maximise or minimise anything, but prices are rather set to permit lower level objectives (for example security, minimum market share) to be attained. Further, prices may be set to achieve certain objectives for the transport supplier in terms of his welfare (this is normally the case of private enterprise transport undertakings), while in other areas prices may be set to improve the welfare of consumers (as has been the case with publicly owned transport undertakings). This distinction is important, as many undertakings consider that the employment of the pricing mechanisms to achieve their objectives is automatically to the benefit of customers.

It is clear that pricing objectives differ depending on the provision of transport services (public or private) and market conditions. The following pricing objectives can be distinguished:

- Economic efficiency[2] ;
- Profit maximisation;
- Cost coverage;
- Environmental sustainability;
- Equity (including redistributive objectives);
- Objectives transcending the boundaries of transport markets, including macroeconomic objectives.

The objective of economic efficiency is usually important to governments, as it reflects the aim to maximise welfare of all inhabitants; this will be discussed in more detail in the following section. Profitability reflects the traditional economic assumption that firms set prices as to maximise profits. Variations on this theory suggest that many undertakings adopt prices that maximise sales revenues (Baumol, 1962) when in an expansive phase, or simply price to ensure that certain satisfactory levels of profit or market domination are achieved (Simon, 1959). A third possible objective is that of cost coverage. Most publicly owned firms are not so much focused on making profits, but rather to stay in business and recoup their costs, often induced to do so for political or fiscal reasons. Protection of the environment has become an important objective for governments in recent years. Transport in general, and road transport in particular, are widely recognised as an important source of pollution which threatens environmental sustainability. Pricing measures have been suggested or introduced to deal with these problems. It is arguable that promoting environmental objectives is consistent with the aim of securing welfare maximisation through economic efficiency, in particular when social welfare incorporates environmental social costs and benefits.

Equity objectives and the distribution of real incomes in society are important issues to a government, reflected in the pattern of taxation and public expenditures. Whilst transfer payments, such as benefits and pensions, are a major means of redistributing income, the provision of services, such as transport at subsidised prices, is often considered to be equally important (United Nations, 2001). Moreover, tax policies (or other policies) aimed at regulating transport and the various possible allocations of tax revenues, will have distributional consequences that may or may not match more generally formulated distributional targets, and may therefore motivate adjustments in currently used (distorted) taxes, which in turn implies that indirect efficiency effects may occur elsewhere in the economy. Finally, public bodies are concerned with macroeconomic policy objectives. Governments usually focus on four target variables: the level of unemployment; the rate of inflation, the balance of payments and the rate of growth of national output (see Stiglitz and Driffill, 2000). The level of investment in, and the pricing of, transport infrastructure and transport services both affects and is affected by macroeconomic policies.

These sorts of objectives are complex and are often not compatible. Whilst there are many transport pricing objectives, economists often focus on the pursuance of economic efficiency alone. Prices that are socially optimal are seen as the first-best benchmark, which is in most cases politically desired.

Nevertheless, an expanding body of literature on transport pricing is emerging that considers pricing and revenue allocation in the context of a wider – general equilibrium – framework, in which (tax)distortions elsewhere in the economy and distributional objectives as represented in social welfare functions are considered explicitly (e.g. Mayeres and Proost, 1997 and Parry and Bento, 2002).

This chapter aims to discuss some important economic principles of transport pricing. The intention is not to provide a complete overview of all economic theory on this, but to focus on relevant issues in the context of the DIFFERENT project. We distinguish two different approaches: the normative and positive economic theory of price differentiation. The normative approach assumes that all actors try to maximise welfare. Pricing is efficient when welfare is maximised. Section 2.2 first explains what efficient pricing looks like and then addresses (more realistic) situations where first-best conditions are not fulfilled. It is divided in two sub-sections: 2.2.1 about efficient pricing and the implications this may have for differentiation of transport prices and 2.2.2, which addresses important complexities that arise

[2] Economic efficiency is concerned with the use of society's resources such that no mutually beneficial transactions remain possible.

from the nature of the cost structure of the transport industry, market distortions and other relevant pricing constraints that makes optimal pricing rather difficult.

The positive theory of regulation and its consequences for price differentiation are discussed in Section 2.2.3. This approach focuses on one particular type of constraint of optimal pricing: the political dimension. Policy makers are often influenced by interest groups and it is therefore likely that prices will not be set at an efficient level. Finally, Section 2.3 draws conclusions.

2.2 THE CURRENT SITUATION

2.2.1 FIRST-BEST PRICING PRINCIPLES AND IMPLICATIONS FOR DIFFERENTIATION

Efficiency: social marginal cost pricing

The concept of economic efficiency is derived from the theory of welfare economics, and is concerned with the allocation of resources in an economy. Welfare economics takes a rather wide view of pricing, looking upon price as a method of resource allocation which maximises social welfare rather than simply the welfare of the supplier (Button, 1993). According to this view, prices should equate with marginal social cost to obtain maximal social welfare. What marginal cost pricing does, in effect, is to result in transport services being provided up to the point where the benefit for the marginal unit is equated with the costs of providing that unit (Button, 1993). Sometimes, private provision of the good or service may also result in maximising the social welfare. Otherwise, regulatory policies may be applied to private companies so that their pricing policy is modified to maximise social rather than private welfare. Deriving socially optimal prices needs an objective function (describing the target to be optimised, in this case social welfare). The most general form of this function is a social welfare function. Formally, a social welfare function has as its arguments the indirect utility functions of individuals (Varian, 1999). These indirect utility functions indicate the maximum utility levels of the individuals at given prices, incomes, and magnitudes of externalities such as congestion and pollution. The social welfare function inevitably incorporates welfare judgements with respect to the distribution of economic resources. These value judgements will be reflected in the policy prescriptions based on the welfare function.

An allocation is to be said first-best, if it maximises social welfare subject to the irreducible technological constraints of production (Dreze and Stern, 1987). A first-best optimum in transport is an allocation defined by quantities of goods, including passenger and freight transport volumes that maximises welfare given the prevailing technology such as vehicle fuel consumption and emissions, and the capital stock including transport infrastructure (MC-ICAM, 2002). This definition encompasses externalities if their costs are internalised in the decisions of agents who generate them and included in their utility functions. Economic efficiency then implies that the full costs of transport services are accounted for, including social and environmental costs (no externalities).

We should mention that this optimal pricing rule only prevails as a market equilibrium under certain conditions, which include:

- perfect competition;
- no distortions in other market segments;
- no externalities;
- perfect information;
- no subsidies or indivisibilities of demand or supply.

Clearly, these assumptions will never be met in reality. This makes first-best pricing very much a theoretical result, which is often used as a benchmark for other, more realistic, pricing approaches.

Marginal cost pricing and behavioural dimensions

Optimal pricing of infrastructure requires that the user charge equals the marginal social costs. Marginal costs are those variable costs that reflect the cost of an additional vehicle or transport unit using the infrastructure. This implies that both user costs (e.g. fuel and time costs) and external costs determine the level of the charge. The distinction between private costs and external costs is not new. Pigou showed already in 1920 in his economic analysis of road pricing and congestion costs that individual users entering the road will only consider the costs they personally bear (marginal private costs), but not the external (congestion) costs (marginal social cost) they impose on other road users (Pigou, 1920). This leads to over-demand and a non-optimal situation. He showed that a levy (a Pigouvian tax) equal to the marginal external congestion costs should be imposed from a social point of view. In this case only congestion costs have been included in the analysis, but the analysis holds for all types of external costs.

There has been a lot of discussion about marginal costs and their central role for pricing in the transport sector in the previous decades (see Rothengatter 2003). One of the most pressing issues is the practical application of the concept of marginal costs in the real world. A critical prerequisite for marginal cost pricing in practice is a sound estimate of relevant marginal costs (MC-ICAM, 2001). This is not evident for many external costs. It requires fundamental knowledge on the mechanisms behind the generation of these costs. This understanding, in turn, demands identification of the different types of activities in which the users of transport infrastructure are involved. These activities may be called behavioural dimensions. Various dimensions can be distinguished, depending on the marginal costs caused by the individuals, including a large variety of external effects (congestion, emissions, noise annoyance, accidents). When we look at road use, this means that optimal individual charges should at least vary according to the following dimensions (Verhoef, 2000):

- the vehicle (technology) used;
- the actual state of this vehicle;
- the number of kilometres driven;
- the time of driving;
- the place of driving;
- the actual route chosen;
- the driving style.

A similar list of dimensions can be composed for other modes of transport. It is needless to say that such a system requires very sophisticated technologies that can monitor information about the actual state with respect to these dimensions, and calculate a charge accordingly (an issue which we will discuss in the next section). This involves a wide range of various critical decisions, both short run (e.g. departure time) and more long run (i.e. car ownership) in nature, which determines charge levels. The great number of behavioural dimensions and categories of external costs to be accounted for makes the task of marginal social cost pricing in providing optimal incentives to transport users to change their behaviour extremely complex (MC-CAM, 2001). Different dimensions may also simultaneously affect several cost categories, making it even more complicated. Table 2.1 (adopted from AFFORD) illustrates this and considers road transport as an example (a similar illustration could be given for freight transport and public transport). Car drivers can respond in various ways to hypothetical first-best pricing. When people do not change to other modes, they may choose to drive fewer kilometres, change departure time, choose another route, or adjust driving style. More long-term behavioural decisions include car ownership and spatial behaviour, which refers to the choice of residence and the location of other activities.

The table indicates the relevance of each dependence on a three point scale. The assigned stars are merely indicative and debatable. That is also the reason for using a three-point scale only. However, the table is illustrative in drawing explicit attention to the dependence between various externalities and behavioural dimensions (Verhoef, 2002). For instance, the way people drive affects congestion levels and accidents (risk levels increase with speed). But it has also a strong impact on noise levels and the level of air pollution. Regarding the congestion externality, Table 2.1 makes a distinction between bottleneck congestion and flow congestion. The main difference is that bottleneck congestion is caused by the existence of physical bottlenecks in the network, such as bridges or tunnels. Flow congestion refers to (limited) road capacity in general. In real networks, observed congestion is often a mixture of both types of congestion. As shown in Table 2.1, bottleneck congestion is independent of the total vehicle*kilometres driven in the network. It depends only on the question of whether a driver wants to pass the bottleneck.

	Car use					Car ownership		Spatial behaviour (location of work, residence)
	Vehicle km	Number of trips	Time of driving (peak/off peak)	Place of driving	Driving style	Fleet size	Vehicle technology	
Intra-sectoral externalities:								
- flow congestion	*	-	**	**	**	*	-	**
- bottleneck congestion	-	**	**	**	-	*	-	**
- infrastructure damage	**	-	-	-	-	*	*	**
- accidents	*	-	*	*	**	*	*	*
Inter-sectoral externalities:								
- noise	*	-	*	**	**	*	**	**
- local emissions	**	*	*	**	**	*	**	**
- global emissions	**	*	-	-	**	*	**	**

** particularly strong and direct relation; * possibly strong indirect relation, or moderately strong direct relation; - no particular strong or direct relation

Table 2.1: Dependence of various external costs of road transport on behavioural dimensions

Obviously, first-best pricing affects all behavioural dimensions. But, as will be shown in the next section, this is not very realistic in practice. We then enter the world of second-best pricing with the consequence that not all dimensions will be affected, or to a lesser extent. For instance, fuel taxes do have an impact on the number of kilometres driven, the number of trips and car ownership, but they do not affect time and place of driving.

2.2.2 Deviations from first-best pricing in transport: consequences for differentiation

The marginal cost pricing concept has been addressed in policy documents for many years. Still three years ago, the European Commission has suggested introducing marginal cost pricing in the transport sector as a general principle from which departures are only admitted in exceptional cases (Rothengatter, 2003). More recently, however, the Commission seems to adjust their views by introducing the concept of 'smart charging', which focuses on the financing of transport infrastructure without mentioning marginal cost pricing (CEC, 2006). As is apparent, it is not so easy to apply this first-best principle in practice. Given the optimality of marginal cost pricing, the question arises why such an evidently attractive instrument has only rarely been used in practical policy making. Apart from issues related to the limited social feasibility of pricing instruments, a different explanation for the low level of practicality may be the fact that reality is often much more complicated than the simple world assumed in theoretical textbooks. This may seriously complicate the determination and application of optimal infrastructure charges in reality.

In this section we first address the transport market. The transport market is characterised by several market imperfections which makes it very unlikely that the market, without regulation, will set transport prices equal to marginal social costs and, therefore, social welfare will not be optimised. Besides market failures, governments may also have other reasons to intervene and adjust prices. Equity is an important reason that deserves attention in the context of price differentiation. The second subsection discusses more practical constraints of first-best pricing.

Deviations from marginal cost pricing

The previous section has shown us that equality of prices and marginal costs leads to an efficient use of resources in an otherwise ideal world. But the real world is not ideal. Actual (market) prices may deviate from marginal costs for a number of reasons. Some reasons result from market failures in the transport industry, in particular:

- Imperfect competition (e.g. monopoly);
- Increasing returns to scale (indivisibilities of supply: fixed capacity);
- Imperfect information;
- Indivisibilities of demand: peak load;
- Externalities.

The pervasive involvement of public agencies in transportation and the failure of these agencies to apply marginal cost pricing principles is caused in part by several peculiar characteristics of the transport market (Gomez-Ibanez, 1999). These characteristics are not unique to transport – some are found in other capital-intensive sectors (such as electricity and telephones). But they make both social marginal cost pricing and private provision seem more complex and controversial than in many other markets (e.g., for a discussion on the adoption of marginal cost pricing in ports, Goss and Stevens (2001) and Haralambides et al. (2001)). When the principle of optimal pricing is applied to the transport sector, it is usually necessary to extend theory in order to deal with certain industry specific characteristics. We discuss some relevant issues in the context of price differentiation. Transportation facilities and services often require capital intensive infrastructure, and vehicle needs (leading to certain industry specific characteristics) may cause particular pricing problems. Specifically, the large fixed investment costs and the joint use of the facilities and services may result in necessary deviations from marginal cost pricing.

Equity is another important reason why actual prices deviate from optimal prices. Therefore we added equity to the following discussion of transport industry characteristics and their impact on price differentiation.

Economies of scale

A characteristic of physical transport infrastructure is the considerable capital costs, which are often higher than the associated operating and maintenance costs for the infrastructure provider (especially on longer distance infrastructure), and can be very long lasting (see also Nijkamp and Rienstra, 1995). Once committed, infrastructure investment usually has few alternative uses and is normally regarded as sunk cost. This fixed component, such as roads, railways, bridges and runways normally give rise to significant economies of scale (marginal costs are below average costs). Once a rail track is laid, the marginal costs of using it falls until a certain capacity level is reached. Firms with large sunk costs and facing economies of scale have marginal costs that are lower than average costs, so that pricing at marginal costs does not generate enough revenue for the firm to be financially self-sufficient. In addition, transport vehicles, such as railcars and buses are also subject to scale economies in operation, though they are generally not as expensive as the infrastructure.

In the long run, however, congestion externalities may show up, resulting in an increase in marginal costs. A toll should be installed which optimally should equal the external costs (Pigouvian charge). A major contribution of Mohring and Harwitz (1962) was to show that the revenues from such a congestion toll will just cover the costs of the facility provider as long as there are no economies or diseconomies of scale in facility capacity, and the facility provider is investing optimally. This holds under certain conditions and concerns optimal highway investment in a first-best world (Lindsey and Verhoef, 2000).

Budgetary problems are especially common in transportation, because transport services often exhibit economies of scale so that marginal cost pricing does not generate enough revenues to cover costs. Ramsey pricing is often suggested to be a solution in order not to deviate too much from efficient pricing. Ramsey pricing minimises the distorting effect of charging more than marginal cost by increasing prices more in those markets where demand is least sensitive to price (Nash, 2001). The basic idea is to charge those customers with the least price elastic demand the largest mark-ups necessary to cover marginal cost and thereby minimise the reduction in consumption that occurs from charging prices that are higher than marginal cost. Commuters, for instance, will be charged more than shoppers, and business travellers more than leisure passengers. It should be noted, however, that this form of price discrimination has itself often been regarded as unfair as it exploits market power to raise the price for the captive user. If the view of equity is that all users should contribute to the cost of that facility in proportion to their use of it, then some form of average-cost pricing is the only admissible pricing policy.

Indivisibilities

Applying marginal cost pricing to transport infrastructure and services is often problematic, because capacity can only be increased in relatively large indivisible units. There are many examples to be found in the transport sector: if the capacity of a railway coach is 60 passengers, then to carry 61 persons requires another coach. Existing airports at full capacity are another example: expansion requires a new runway and terminal facilities. It is often extremely costly to make (small) additions to physical capacity. The issue is one of optimal investment timing, since, under conditions of growing demand, there will come a point at which an increase in capacity will be worthwhile. This brings us to the distinction between short-run and long-run marginal costs.

In specifying the marginal cost-pricing rule, it is important to understand the distinction between short-run and long-run marginal costs. The distinction arises because different factors of production, used in providing transport services, have varying degrees of fixedness or variability over various business planning horizons (United Nations, 2001). Airports, for example, facing increased demand may be able to increase throughput in the short term, whereas in the longer term the operator is forced to invest in new infrastructure (e.g. a terminal or runway). All costs are essentially fixed in the very short term, and, conversely, in the long run, all inputs and costs are ultimately variable (Braeutigam, 1999). Over a planning horizon, it is important to identify those costs that can be varied (variable costs) and those which cannot be varied (fixed costs). Prices should normally be set in relation to short-run marginal costs, which may be higher, lower, or equal to long-run marginal costs.

What this means for optimal pricing and optimal investment can be illustrated with an airport example (investment in a terminal). The initial marginal costs of using a terminal will be very low, so the price is low when set according to short-run marginal costs (excluding investment costs). There is no need for new investment as there is spare capacity. If the demand function shifts outwards over time, the marginal costs will (sharply) increase due to congestion effects. A new terminal might be needed now. When the price in the peak period consists of operational costs (including that of additional investment), the corresponding demand will give a clear indication of the necessity of the investment. Continuation of excess demand with these LRMC charges justifies investment in a new terminal. In the long-run optimum, SRMC=LRMC may apply (Mohring-Harwitz type of equilibrium: see economies of scale).

The previous essentially implies that marginal cost pricing could produce fluctuations in price before and after capacity adjustments are made. Further, whether or not the airport makes a profit depends on whether the price lies above or below the long-run marginal cost curve. The terminal might be profit or loss making at any moment. The investment is worthwhile, when the net present value of the investment in additional capacity is positive over its life time. Such fluctuations in prices and profits are likely to be undesirable, but unavoidable, because any other pricing pattern will produce welfare losses. Prices above marginal costs during times of excess capacity will cause underutilisation. If price caps are set, during periods of excess demand, non-price rationing methods will be required.

Common and joint costs

A related set of pricing complications occurs because transportation firms often use the same facilities, equipment and labour to produce different services: they are multi-product firms. This leads to the conceptual and practical problems of determining transport prices associated with fixed and variable costs and choosing the relevant time period because many costs may also be ‘joint’ or ‘common’ to a number of users. Pricing in these circumstances may be difficult, as it is not always clear how to allocate costs between products. This may make it difficult to determine marginal costs. Joint costs exist when the provision of a specific service necessarily entails the output of some other service or product at little extra expense (Gomez-Ibanez, 1999). The classic example of jointness is the return trip, where the supply of a transport service in one direction normally implies the provision of a return service (Button, 1993).

Common costs are similar to joint costs, in that they are incurred as a result of providing services to a wide range of users, but differ, in that the resources used to provide one service do not unavoidably result in the production of other services (United Nations, 2001). An airport, for example, faces considerable common costs. A terminal is used by different types of users: terminal retailers and air passengers. The same holds for runways, these are used by different types of planes. The allocation of these common costs among users poses particular practical problems, which consequently also leads to pricing problems.

Monopoly

Firms facing the previously mentioned aspects, such as high fixed costs and economies of scale, together with significant indivisibilities in the provision of capacity, have limited competition. These circumstances, often the case in the transport industry (particularly in terms of infrastructure), give rise to monopolies. Under these conditions, and a fairly small transport market relative to the optimal size, a good or a service can only be produced at least cost if only one firm is engaged in its production and a natural monopoly is likely to emerge. Public transport companies are often claimed to be a natural monopoly, although there may be little evidence of scale economies (Gomez-Ibanez, 1999).

Imperfect competition creates a major distortion in the market for transport services. There is every risk that the monopolist will not provide optimal transport prices, and an unregulated market will therefore not lead to the maximisation of social welfare. In such circumstances, the government may decide to intervene either by directly providing the transport services or by regulating prices.

The existence of declining average costs in the transport industry is an important reason for the emergence of natural monopolies in many sectors. The potential monopoly power and the possibility of abuse of this position may be reflected in high prices (or price discrimination) and has often led to government price regulation and public ownership. This is, for instance, the case in the airport industry. Governments are afraid of private airports setting inefficiently high prices. Therefore airports are often in public hands, or privatised airports are (price-) regulated. When governments take over, and prices are set equal to marginal costs, it is obvious that a subsidy is needed. It may also be possible to look for pricing policy options to assist cost recovery while at the same time minimising the resulting allocative efficiency losses. Two-part tariffs (consisting of a fixed charge per consumer and a variable charge per unit consumed) and Ramsey pricing have been suggested in these cases.

Externalities

The transport industry is characterised by various externalities. The essence of an externality is that it involves (i) interdependence between two or more economic agents, and (ii) failure to price that interdependence. Formally, externalities exist when the activities of one group (either consumers or producers) unintentionally affect the welfare of another group, without any payment or compensation being made (Button, 1993). Most attention in transport is paid to the negative (costs) externalities, although also positive externalities (benefits) have been identified (for a discussion on this latter issue, see Verhoef (1996)). It is quite clear from everyday experience, that there are costs associated with transport that are not directly borne by those generating them. Transport generates many negative externalities, including noise, accidents, pollution, and congestion. Road travellers, for example, impose noise and vibration costs on those living adjacent to highways.

A result of the clear presence of externalities in transport is that the early neo-classical writers studying market failures frequently illustrated their viewpoints using transport examples. Dupuit was in 1844 one of the first to illustrate efficient pricing of public goods (Button and Verhoef, 1998). Coase (1960) considered the absence of property rights in relation to the existence of externalities for a railway.

Another well-known example is that of a congested road, including optimal congestion charges (Pigou in 1920). They all showed that the market mechanism fails to allocate resources efficiently.

The existence of externalities has been one of the main motivations for governments to intervene in the transport industry. Economists have argued that a correction of transport prices should take precedence. The previous section has shown that optimal taxation (dealing with all types of external costs) has as a consequence that the charge will be highly differentiated according to many behavioural dimensions. However, policy makers may decide, for instance, to focus only on congestion. Despite lower efficiency, it would considerably reduce the complexity of the pricing mechanism since location and time are the two remaining dimensions to be considered.

Equity

Finally, transportation often raises equity concerns that seem to conflict with marginal cost pricing. Marginal cost pricing clearly results in very differentiated charges with the consequence that no one transport user pays the same price which may be perceived as unfair. Equity is important in the context of the acceptability of pricing. Many stakeholders raise objections about pricing measures that they perceive to be unfair. If a pricing measure is unfair either to themselves in relation to other people or to people perceived to be less well off in society, then there could be significant acceptability problems. Transport pricing is often perceived as a form of regressive taxation, allowing only those with enough money to access a resource (e.g. infrastructure) that was once considered free. Implementation strategies are therefore discussed that allow certain sections of the community to be exempted from pricing, or compensate some groups with a lump-sum transfer. The problem of who should receive extra benefits (e.g. tax exemption) and the wider problem of making sure price measures are both equitable and perceived to be so, are important issues to be included in any successful implementation strategy. Here the concept of price discrimination shows up. In public transport, for instance, it is common that different prices are charged for the same service. The fare policy of governments may benefit particular groups of society, e.g. the elderly.

The public finance and tax literature makes a distinction between horizontal equity and vertical equity. Horizontal equity refers to the principle which states that those who are in identical or similar circumstances should pay identical or similar amounts in taxes (Stiglitz and Driffill, 2000). It requires that those with equal status - whether measured by ability or some other appropriate scale - should be treated the same. If, for instance, income were the only measure of a person, then two persons with equal incomes would be treated as equals. Vertical equity states that people who are better off should pay more taxes (Stiglitz and Driffill, 2000). This generally requires that those with less ability to pay are treated favourably relative to those with greater ability.

The role of these concepts in transport can be illustrated by describing the implementation of road pricing and the use of the revenues. Horizontal equity implies that similar users should pay identical tolls. But the question who ‘deserves’ the benefit (or revenues) according to this criterion is a matter of debate. It can be defined as those who actually pay the toll, or it could also include those who change their behaviour (travel pattern), thereby incurring costs in terms of inconvenience, and providing congestion reduction benefit to the toll payers. So the difficulty is that the initial users of the road have become ‘unlike’ after the implementation of the charge, and should be compensated. The use of road charges to fund public transport is an example. Horizontal equity is further complicated by the existence of externalities from motor vehicle use, including accident risk and environmental degradation. That vehicle use imposes costs on other people itself represents horizontal inequity. If the criterion is horizontal equity and external impacts are recognised, then revenues may be used to compensate for external costs (Litman, 1996). Funding candidates may include environmental and social programmes that mitigate the harm of motor vehicle use. However, compensation for external costs may, in turn, induce inefficient behaviour by the recipients of externalities in the sense that insufficient incentive is provided to avoid incurring the externality (Oates, 1983; Verhoef, 1994). This implies that (also) from this perspective, there may be trade-offs between efficiency and equity in the regulation of externalities.

Vertical equity is concerned with the treatment of individuals and classes that are unlike. By this principle, the distribution of costs and benefits should reflect people’s needs and abilities. Progressive tax rates, and need-based services such as programmes to help the poor, seniors, and disabled people, are examples of policies reflecting vertical equity. Vertical equity is often measured with respect to income. This is an imperfect metric, since people with the same income often have very different needs and abilities. Road pricing is usually considered vertically inequitable because charges impose a relatively larger burden on the poor. For example, a €2 per day toll might be horizontally equitable (everybody pays the same amount), but vertically inequitable because it represents a larger portion of income for a lower-income driver than for a high-income driver. This fact is tempered by the fact that lower-income people drive less on average than those with higher incomes.

Another equity issue refers to spatial or geographical equity, which is concerned with the treatment of individuals located in various regions or cities. Congestion pricing could be considered as unfair from this point of view, as charges (depending on time and place) will differ among regions. Another illustration of spatial equity concerns in transport is the experience of Sydney City Council, which decided that transport availability should not depend on the geographical area in which a person lives. Transport services should be available equally to people across the Sydney metropolitan region.

Constraints on marginal cost pricing: second-best pricing

Social marginal cost pricing assumes a theoretical first-best world. Such first-best pricing is increasingly recognised as being of limited practical relevance, but it might serve as a useful theoretical benchmark. Besides the previously described reasons for market failures, various constraints and barriers may exist that prevent a regulator from charging (optimal) prices that it ideally would like. Verhoef (2002) mentions the following important constraints:

- Technological and practical constraints: first-best pricing requires charges that vary continuously over time, place, route chosen, type of vehicle, driving style etc, which might be too sophisticated and not understood by drivers or impossible to implement under available charging technologies;
- Acceptability constraints; there may be too much resistance and uncertainty (e.g. about objective and necessity of the measure) that may make it preferable to start with a few small-scale demonstration projects;
- Institutional constraints; one example is where local or regional governments cannot affect some transport charges that are set by a higher level government;
- Legal constraints; ideal prices might not be possible on the basis of legal arguments (e.g. when taxes should be predictable)
- Financial constraints; for instance the prior definition of minimum or maximum tax revenue sums to be collected;
- Market interaction constraints; transport taxes will have many consequences for other markets, among the most important is the labour market;
- Political constraints: charges may become a political issue much more than an economic question.

Under such conditions, the regulator has to resort to second-best pricing: setting the prices that are available optimally, under the constraints applying.

This has led to some discussion on the practical relevance of marginal cost pricing. Rothengatter (2003) argues that marginal cost pricing is no longer optimal when aspects such as acceptability and institutional consequences are introduced into the analysis, and a real-world pricing system can therefore not be based on abstract economic theory. Nash (2003) replies that indeed difficulties and uncertainties remain (which should be carefully considered), but that there is no need for a totally different theoretical approach, since marginal social costs are the correct starting point in the development of any efficient pricing policy.

Given these constraints and discussions, economic research has focused on setting prices that are available optimally, under the constraints applying: second-best prices. Examples of second-best tolling include the use of toll cordons around cities instead of tolling each road in the network, and the use of step tolls instead of smoothly time-varying tolls. It is safe to state that second-best pricing will be the rule for the implementation of marginal cost-based pricing in reality. Much of the relevant literature is reviewed in Lindsey and Verhoef (2001), whereas MC-ICAM (2002) gives insight into the kind of analysis. We discuss two relevant subjects in the context of price differentiation.

Networks

First-best pricing in a network assumes that each link of a road network is efficiently priced. This is often impossible due to excessive costs, the requirement of toll-free alternatives by governments, and the likeliness of incremental implementation. The question under study is then how second-best tolls should be set on toll roads, given un-priced congestion on un-tolled roads elsewhere in the network.

This network problem is one of the most widely studied, where the simplest version concerns a simple network in which there are two links connecting the same origin and destination. Verhoef et al. (1996) demonstrate that, if one of the links is often congested, the optimal second-best toll of the other link can be negative. This study also shows that the optimal toll depends on the relative free-flow travel times and capacities of two routes, and on the price elasticity of travel demand. Welfare gains from second-best pricing are, according to this study, a small fraction of the benefits from the first-best benchmark (only 10%). Other studies have looked at ways to enhance efficiency and have incorporated the possibility of dynamic (time varying) tolls, and sorting of drivers according to value of travel time. This does indeed yield higher absolute efficiency gains.

Most network studies assume a unimodal network. In reality, a traveller has the possibility to choose between modes. The leading example is the choice between public transport and the private car. Tabuchi (1993), for example, uses a second-best framework which is characterised by a road, subject to bottleneck congestion, that runs parallel to a railway. Assuming inelastic demand and average cost pricing of rail trips (to stay in business), it is shown that the road share of travel is highest with an optimal (time-varying) road toll, and successively lower with a step toll, a uniform toll, and no toll. Another study that reviews second-best choices in a transport network with two modes is by Arnott and Yan (2000). The main difference between second-best problems on networks and those for mode choice is that, in the former case, an assumption of perfect substitutability is often made. Although, at first sight, the two-mode problem appears to be relatively simple, it has proved to be difficult to solve (MC-ICAM, 2002). Results are very much restricted by the assumptions made (such as fixed capacity and a fixed toll) and often complicated and difficult to interpret.

Second-best studies have not only addressed the issue of the level of second-best tolls in different types of networks, but recently the toll location has also been included. Verhoef (2002) examined the selection of individual toll links, and the determination of toll levels using some sensitivity indicators. Yang and Zhang (2002) considered selection of optimal toll levels and optimal locations for achieving maximum social welfare using a bi-level programming approach with both discrete and continuous variables. And Shepherd and Sumalee (2004) explored the usefulness of solving the optimal toll problem for a medium scale network.

Heterogeneity

Travellers and road vehicles differ in a number of characteristics. Vehicles vary, for example, in the road space they occupy, and in weight and acceleration capabilities. Travellers have different values of time, desired speed, and so on. First-best pricing often makes it necessary to distinguish between different vehicle types and users (because of different marginal costs). It is important to know whether first-best congestion pricing can still be implemented, given these dimensions of heterogeneity, and if not, how second-best tolls are optimally determined. In this context a distinction is often made between anonymous tolling schemes (independent of vehicle type and driver) and non-anonymous (type-specific) tolls.

Many studies have been conducted on the implications of the problem of heterogeneity and pricing. The topics range from heterogeneity in drivers' values of time and trip-timing preferences to the heterogeneity in travel speed. Another example of a study that is of interest here is that of Verhoef and Small (2004), who consider a differentiation of tolls across parallel traffic lanes by using a static model. They show that an anonymous toll may still be optimal on each lane separately, and efficient segregation of drivers is achieved without regulation. It should be noted that the extra gains are rather small, so that a second-best single toll applied to the entire highway does not impose much of a welfare loss. Optimal anonymous tolling may entail segregation of vehicle or driver types onto separate routes.

2.2.3 THE POSITIVE THEORY OF INFRASTRUCTURE CHARGES

We have seen that various constraints can be identified which make first-best pricing rather unrealistic in practice. The last constraint mentioned in the previous section was the political one. Economists generally assume governments and politicians will maximise welfare of their citizens. They may still do so when facing constraints of equity, cost coverage or cognitive limitations of the users. This will affect differentiation of the charge, but welfare is still maximised. However, politicians may well have different objectives leading to deviations of optimal prices.

The following sections assume that politicians and civil servants follow their own individual goals and that, in doing so, they are open to the influence of Special Interest Groups (SIGs)[3]. This does not necessarily mean that under this approach decision makers never care for public welfare. First, there are limits to the discretion of decision makers due to competition for their offices. Second, there may be cases where following public welfare coincides with individual interests. Third, and perhaps most important, the decision maker must convince the public of his policies; usually this cannot be achieved without at least some regard to normative argumentation. Nevertheless, there may be cases where real-world policies can be better explained by assuming individual utility maximization than welfare maximization on the part of decision-makers.

Departing from the axiom of welfare maximization means that instead of asking how transport pricing *should* be set (in order to achieve economic efficiency, i.e. a maximum of welfare) we ask how transport prices are *actually* set under real world conditions. In economic jargon: we are moving from the *normative* to the *positive* approach of economic theory.

This change of perspective does not mean that the two approaches have no connection (in the sense of two different "schools" of economic theory or the like). As was just explained, there are often cases where both approaches make the same predictions. In addition, there is the need for every policy-maker to take normative considerations into account, if he wants to be re-elected. Furthermore, one may argue, as was done in the introduction to this section above, that the change of perspective amounts simply to adding "the political constraint" to marginal cost pricing. This is a matter of semantics, of course, which should not detract from the fact that both the normative and the positive approach use the same apparatus of economic theory. The change from positive to normative analysis therefore means no radical break in the overall approach in this part of the DIFFERENT project. Rather the two approaches are complementary, or one may also say that one is a special case of the other, depending on perspective.

In the following sections the positive approach will be applied to the problem of tariff differentiation in transport. It must be said, however, that the literature in the positive branch of economic analysis on this question is far less developed than in the normative branch. An important part of the work done in DIFFERENT will therefore be experimental in the sense of applying existing literature on *related* topics to transportation pricing. The following sections show which parts of the positive theory might be good candidates for such an application. The adaptation and application itself remains to be done. Consequently, some discussions may be more abstract compared to the normative analysis.

Special Interest Group theories

Special Interest Groups are always interfering with the political process. Noll (Noll, 1989) names two major reasons why interest groups are formed: first they are formed to solve the problem of powerlessness and second to counter the problem of controlling politicians.

[3] In a world without special interest groups the policy maker would try to maximize overall welfare. The existence of SIGs makes, therefore, the incorporation of the political constraint necessary in order to derive "real world" conditions. Thus, from the positive theory point of view, policy makers and SIGs are the main actors participating in the political game.

Due to the fact that a single voter is powerless against the politicians, the forming of special interest groups enables voters to express the intensity of their preference for certain policies far more clearly than just through the voting process. Likewise, controlling the performance of some politicians may be far too costly for any individual voter, but not for a special interest group that can distribute these costs over the number of its members.

Special interest groups engage in many activities. The most important are:

- to gain access to policy-makers;
- to supply policy makers with information;
- to support the election campaigns of their favoured candidates;
- to "educate" the general public on their favoured policy.

Although all of these activities can be observed in reality, it is not clear that they really buy influence. Empirical studies so far do not seem to offer clear evidence on this point (Grossman/Helpman 2001). The main problem here is that studies of the effects of the activities of interest groups must compare the "real world" situation to the imaginary situation where interest groups would not have been present.

For the purpose of the following discussion, two of the above mentioned activities of interest groups are of special relevance: campaign contributions and the provision of information.

Campaign contributions

Campaign contributions have the aim to exert influence on decision-makers to implement a certain type of regulation, e.g. a certain type of pricing policy.

The main model, which initiated the economic research in the direction of interest groups, is the well known Stigler/ Peltzman model (Peltzman, 1976). This paper, in turn, was based on an empirical study by Friedland and Stigler (1962) which stated serious objections regarding the effectiveness of regulation of electric utilities. Friedland and Stigler formulated an econometric model to test the effect of regulation on electricity prices. Their result was that regulation had an insignificant effect on the average price of electricity. Apparently, regulation in this industry was pro-producer rather than pro-consumer. This led Stigler to the concept of "regulatory capture" (Stigler 1971). The term "capture" here means that after a while the regulatory agency becomes an instrument of the industry it is supposed to regulate. According to Stigler the main reasons for that are as follows:

- Regulators gain from supplying regulation;
- The industry likes regulation, because in most cases regulation also means restriction of competition;
- The consumers are not well informed and not well organized;
- The producers can form small but well organized interest groups.

The standard model of this process of regulatory capture is the Stigler/Peltzman model (Peltzman 1976, 1993). Methodically, it is a similar approach to the microeconomic utility maximization model (Figure 2-1). The main aim of a politician/regulator is to stay in office. To that aim he or she tries to maximize net votes. This is modelled by assuming a so-called voting function (political support function), the level of which is depending of the price P and the industry profits Π. This function has the form: $M(P,\Pi)$.

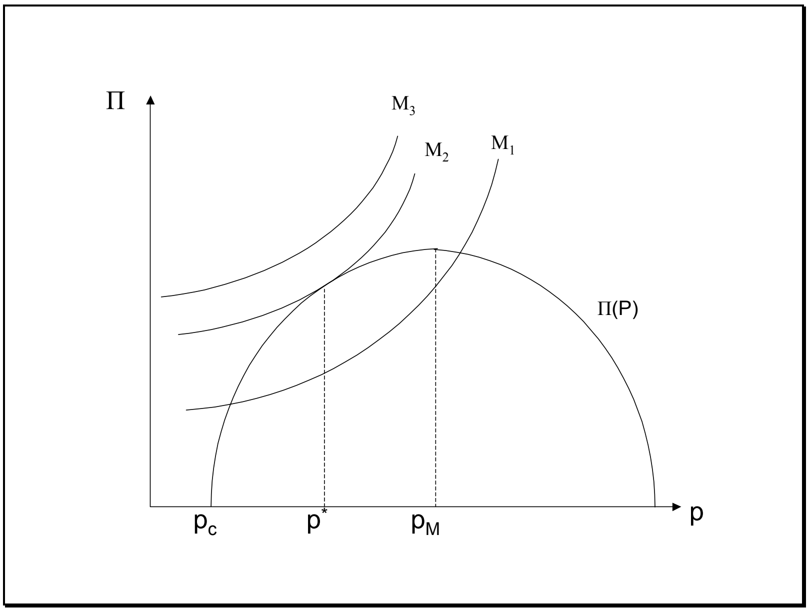

Figure 2-1: Optimal Regulatory Price in the Stigler/Peltzman model (Source: Peltzman 1976)

The regulator's aim is to find the optimal price that maximizes the political support. Due to the fact that the industry profit Π(p) is a function of the price, the optimal choice for a regulator is the tangential point between the profit function and the "Iso-Support-Curve"(constructed from the political support function). This situation is depicted in Figure 1. M_1, M_2 and M_3 are the mentioned "Iso-Support-Curves". Each one of them depicts all the possible combinations of price and profit and represents a certain level of political support. Upper "Iso-Support curves" indicate higher political support for the policy maker. In Figure 2-1, M_3 corresponds to higher political support compared to M_2 or M_1. Their slope is according to their definition positive; higher industry profit increases political support by the interest group, whereas higher prices reduce political support by the voters. Π(p) is the industry profit function. The optimal price for the regulator P^* lies between the competitive price P^c and the monopoly price P^m. At P^c the profit for the industry is zero. At P^m profit reaches its maximum.

However there are several weaknesses of this type of model. The major weaknesses are the following:

- First, the influence on a decision maker increases with the group's contribution. This empirical knowledge, however, hasn't been treated in the Stigler/Peltzman model.
- Second, it is assumed, that the candidates will indeed implement the political program as promised to the interest groups.
- The related problem of credible commitment is not mentioned.
- Frequently political support models of the Stigler/Peltzman type contain just three groups of actors: the producers of the good in question, the consumers and the regulators. In reality there are normally far more interest groups than just consumers and producers.

The next important step in the development of the positive theory of regulation was the contribution of Gary Becker (1983, 1985), where regulation is modelled as an equilibrium of the political pressure of competing interest groups. If all SIGs are represented equal in the political process, then the result will be relative "efficient". If not, the policy choices will yield monopoly rents.

Politicians, political parties and voters are not explicitly modelled in Becker's approach. In this sense Becker's model is a model without institutions. Individuals belong to particular pressure groups defined by certain characteristics. These groups use their political power to enhance the welfare of their members.

Even if Becker does not use prices in his model, his approach is indirectly associated with them, since increased welfare for the members of an interest group is also a matter of the existing price level and pricing scheme.

Becker and the authors that used this type of model describe the result of lobbying activities using a so-called “influence function”, that relates the political influence of each pressure group - expressed by the benefits the members of a group receive - to the pressure exerted by the given group and to the countervailing political pressure exerted by all the other social groups. This model is a zero-sum game, in which increased political influence of one group decreases the influence of others.

Becker also stated that a key issue for an interest group is the number of its members. An increase in the number of members can raise on the one hand the resources available for lobbying activities, but on the other hand can cause the free rider problem[4] within the group. One important implication of the Becker-Model is that, if a SIG can keep the free rider problem under control, then it is very likely to succeed.

An important dimension of research using the Becker-type model is the rent-seeking literature. Rent seeking describes the behaviour of persons, firms, or groups which are willing to spend money in order to achieve uncompensated welfare. An example may be the rent connected with a monopoly granted by the state. The more resources an interest group spends to gain this rent the higher the probability that it will get this rent.

Keeler’s contribution (1984) to the positive theory of regulation consists in a development of the Stigler/Peltzman and the Becker model in two dimensions. First, the Stigler/Peltzman model and the Becker model had high explanatory power on the question why regulation occurs, but they could hardly explain deregulation. Second, Keeler observed, that in some cases politicians’ behaviour seems to be the basis of the Stigler/Peltzman paradigm. In other cases, however, politicians seem to behave very close to the normative theory point of view. Therefore, Keeler tried to solve these two problems by using positive and normative features in his model.

The main improvement in Keeler’s model is the use of the each group’s Consumer Surplus in the Stigler/Peltzman’s political voting function:

$$W = W(CS_1, CS_2, \ldots\ldots\ldots\ldots.., CS_n).$$

CS_i: Consumer Surplus of group i.

The use of Consumer Surplus in Keeler’s model shows the importance of the price for each interest group. A price level (or a pricing scheme) that maximizes one interest group’s utility does not necessarily maximize the utility of the rest of the interest groups.

Various researchers used models that are similar to the Keeler approach. In these models regulators look for policies that maximize a weighted representation of the utilities of different social interest groups.

The best known application here is the Grossman/Helpman model. The Grossman/Helpman model is a foreign trade model. The model refers to international trade with two goods (footwear and electronics). There are two factors of production which are represented by two interest groups (capital and labour). A tariff on footwear would have a positive impact on the real wage of labour, whereas a subsidy on the export of electronics would affect positively the income of capital. All individuals own either capital or labour, but not both. The policymaker has the task to choose a tariff rate and a subsidy level in order to maximize a weighted sum of aggregate welfare and campaign contributions.

Using methods of game-theory Grossman and Helpman showed that in the equilibrium of the game it is indeed the politician’s optimal behaviour to maximize a weighted sum of the welfare of both capitalists and labour. This means that the politician will indeed maximize an objective function, which

[4] The term free rider describes a person within a group who benefits from the policy carried out by all other group members without bearing the respective costs.

includes political contributions from organized lobbies and also aggregate welfare. From this point of view, the tariff can be seen as a compromise between competing interest groups and the regulator.

In this model the whole population of this economy belongs either to the group of capital owners or to the group of workers. However, in reality such an exact division of citizens is impossible and not realistic. A "real world" test of the Grossman/ Helpman model would probably yield a falsification of the model's predictions. Still the model is important in pointing out a promising methodological approach, which may also be useful with respect to road pricing.

Provision of information

The provision of information as an activity of SIG's is extremely important. Although the provision of information is not directly connected to matter of prices, it is crucial for a SIG to act on that field, in order to gain access to the policy-maker. In addition provision of information has the aim to convince a policy maker that the group's most favourite policy is also the best one. Politicians are interested in such information because in most cases they have of less information and in addition they have limited resources available to gather it. A SIG in contrast has access to cheap information because of the highly specialized knowledge of its members and because of the fact that information costs can be spread among its members.

Due to the fact that a politician has limited time to listen to interest groups, he will separate "important" from "less important" groups and "valuable" from "less valuable" information. In doing so campaign contributions may be a helpful means. This means, the more a group contributes to a policy maker, the higher the probability to be heard.

Given, however, that a SIG has gained access to a certain policy-maker, it faces, first, the problem that the politician may have different policy aims than the SIG and, second, the problem to convince the politician of the credibility of the information supplied.

Concerning the simplest variation of the existing models, Grossman/Helpman's research on this topic showed that first the policy- maker will always prefer information from moderate SIG's and second the optimal strategy for the SIG's is not to give very precise estimates. A level of information which includes ranges of values increases the credibility of the lobbyist.

The credibility problem of the SIGs becomes far sharper when the political parties have already taken their position with respect to the political issue in question. In particular when the SIGs have to issue their statements close to election time, credibility will become the major problem. The citizens know that the SIGs will try to influence their information in favour of their favourite party and will evaluate this information accordingly.

Positive theory and price structure

So far it has been shown how Special Interest Groups are interfering in the political process in favour of their members (campaign contributions, provision of information). In the models mentioned above, prices are playing an important role; however these models are considering the price level, not the price structure. This subsection gives an example of price structure superiority.

It is very difficult in the highly developed transport sector of the EU to achieve Pareto improvements[5] through transport policy measures (e.g. pricing schemes). In general, such measures create winners and losers. This fact makes it very likely that SIGs will try to affect pricing schemes in favour of their members. Laffont (2000) picked up this topic and researched the conditions of superiority of this type of second-best pricing.

Arguments for infrastructure pricing have already been made by Adam Smith. Smith's proposals on this topic concern full cost recovery and a tariff proportional to marginal cost. Laffont used the Smith pricing rule as a basis of comparisons to other forms of infrastructure charges, namely a 2nd degree price discrimination.

5 A Pareto improvement can be reached if an economical measure enhances welfare for at least one person without making anyone else worse off.

Smith starts from the principle that price should equal marginal cost. This, however, leads to a deficit as described above. Therefore Smith proposes to inflate marginal cost prices by a constant mark-up, so that, overall, total costs are covered. Formally:

$$p_i = \delta\, MC_i \text{ and } TC = p_i\, q_i.$$

p_i : tariff for user i
TC : total cost of the infrastructure facility,
MC_i : marginal cost of user-type i,
q_i : quantity of infrastructure services consumed by type i
δ: constant factor.

From the normative theory point of view the Smith rule is inferior compared to pricing schemes such as Ramsey or non-linear pricing, because it causes welfare losses. Laffont however, argues that this result may change when SIGs affect the pricing scheme.

Laffont's model describes an economy consisting of two groups, which differ with respect to the utility they derive from the output of a certain monopoly, for instance the highway network. These two groups alternate in power with a certain probability. This assumption enables this model to calculate with alternating power situations. The natural behaviour of each group (when in power) is to implement such policies (concerning the level of production and the tariff structure) that maximize its own welfare. The group in opposition must accept the policy made by the other group so that its welfare is a function of the policy made by the group in power.

Laffont now compares two situations. In the first situation, the Smith rule has been implemented as the pricing principle in the country's constitution. The word "constitution" here should not be interpreted too literally. It means that a basic political decision has been taken to implement a certain tariff-model, perhaps very akin to what the EU-Commission has been searching for over the last two decades with respect to infrastructure charging. In the context of road pricing, one could compare this to a situation where a law has been passed that implements a uniform tariff for all vehicles based on marginal cost but with a mark-up designed to guarantee full cost recovery. In a sense this is the case with respect to the German HGV toll.

In the second situation, the 2nd degree price discrimination is implemented in the constitution. The groups can choose between two two-part tariffs. One such two-part tariff is shown in Figure 2-2. In 2nd degree price discrimination a user has the choice between two of these tariffs: depending on whether he is a low use customer or a high use customer, he will choose a tariff with a high fixed component F and a low usage fee p or vice versa. In this way customers "self-select" into two customer groups. If the firm in question designs the two tariffs in the "right" way, each group will select the tariff that is "made for it". If this is the case, the two tariffs are said to be "incentive compatible" or to satisfy the incentive compatibility constraint.

In both cases this means that after the basic decision for a tariff-model has been taken, the *structure* of the financing scheme cannot be changed any more, but only the *level* of its various components.

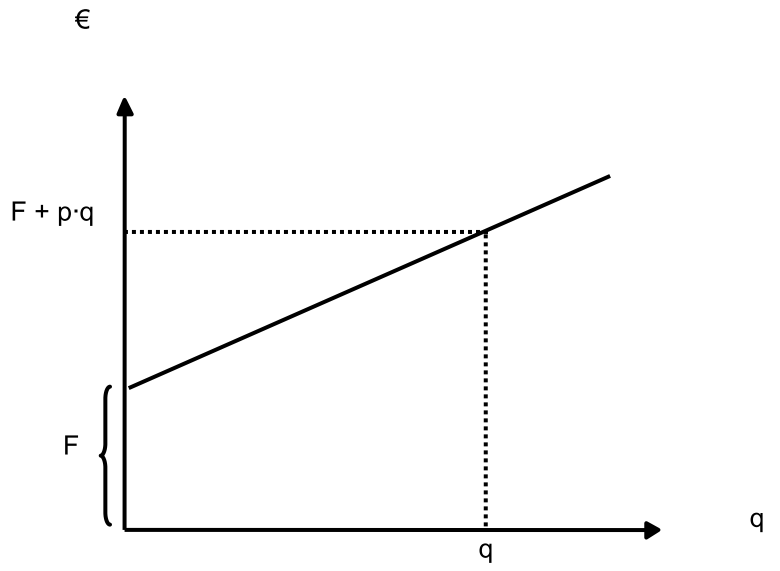

Figure 2-2: Two-part tariff (Source: Viscusi et al., 2005).

But in the case of the Smith rule the group in power has no room to decide on the structure of the tariff, because the Smith tariff is a uniform tariff. It can only decide on the production level of the natural monopoly and, as a consequence, on the level of the mark-up. Nevertheless the decision of the level of the mark-up has an impact on *both* groups. As a result the group in power can stipulate a production level according to its consumption preferences, but it has limited room to move the financial burden to the other group.

This is different in the case of the two-part tariff. It is natural that the groups will choose the two-part tariff that maximizes the group's welfare, and this depends on how intensive the two groups use the infrastructure facility. In this case, the group in power now gets the opportunity to shift a larger share of the financial burden to the other group by consuming more or less than optimal. This means that the group in power has enough room to manipulate the two tariffs in such a way that it can maximize its own welfare at the cost of the minority.

Laffont compares the total expected welfare in both situations. He arrives at the result that the Smith rule causes less distortions of *expected* welfare than second degree price-discrimination. However, there are limits of the Smith rule's superiority:

1. It becomes worse (from a welfare point of view) the higher the fixed costs. After a certain point second degree price discrimination is superior to the Smith rule.
2. Its welfare performance depends also on the degree of heterogeneity of the two groups (with respect to the utility they derive from the consumption of a monopoly's output, e.g. the highway network). In that case, it is impossible for the group in power to shift financial burdens to the other group. Regarding their consumption behaviour, both groups can be seen as one. Hence, if there is no scope for the one of the groups to shift financial burdens to the other, the welfare losses of the Smith rule are higher than the ones of the multipart tariff, and the Smith rule becomes inferior.

Even if Laffont's model gives enough room for criticism, it still has high explanatory power and opens new perspectives for the treatment of cases that involve tariffs and alternating majorities. Moreover, as far as we know, it is the first model which centres on the structure of tariffs, not just the level. As such it is of high relevance for the question of the differentiation of tariffs and therefore for the DIFFERENT project. Laffont's model shows that it is important to consider aspects of the positive theory and to look for realistic solutions concerning tariff structure proposals. However it will not always be the case that the Laffont results are applicable. Therefore it is highly important in every different case to study the precise framework conditions which apply to this case.

2.3 CONCLUSION

Several transport pricing objectives can be distinguished, such as economic efficiency, profitability and cost coverage. Economists will usually argue that the pursuance of economic efficiency should take precedence, in any case as long as political power does not indicate its preference about redistribution and equity. The concept of economic efficiency is derived from welfare economics, and is concerned with the allocation of resources in an economy. According to this theory, prices should be equal to marginal social cost (throughout the economy) to obtain maximum social welfare. With this pricing principle, potential travellers who value their trip above the costs they impose by adding to traffic flows will travel. Those who value their trip below that cost will not travel or use some alternative means. Such an optimal price is based on all costs involved with driving one additional kilometre, or one extra transport unit using infrastructure. Because this also includes external costs, these charges are highly differentiated and vary along with variations in many behavioural dimensions.

Such a first-best setting is recognised as a useful theoretical benchmark, but it is of less practical relevance. The regulator faces several barriers and constraints preventing it from setting optimal prices (e.g. technical or political in nature). Less differentiated price structures will be less optimal, but they are more realistic. Economic theory offers several options that are second-best: optimal given the constraints applying. Most likely these pricing measures will be differentiated according to a fewer number of behavioural dimensions, reducing the complexity.

Additional insight can be gained from adding the positive view of economic analysis to these normative considerations. By introducing the influence of special interest groups into the analysis one arrives at further (political) constraints on pricing policy. The main purpose of adding these policy based constraints is to be able to design tariffs which are as little amenable to political manipulation by interest groups as possible. It may be the case, for instance, under certain political circumstances that a uniform tariff (e.g. for a road) may lead to higher expected economic welfare than a highly differentiated tariff because the uniform tariff is less likely to be manipulated by politicians wanting to favour certain user groups (e.g. local residents vs. long distance travellers).

The overall picture, which takes both the normative and the positive way of analysis into account, should be able to provide guidance as to the desirable degree and direction of price differentiation in transport.

3 BEHAVIOURAL THEORY

3.1 INTRODUCTION

In the transport sector differentiated pricing is increasingly used to manage the user's demand for infrastructure capacity, thus influencing behaviour. To describe behavioural changes induced by prices, economists use the concept of price elasticities. Price elasticities describe the extent to which people change (consumer-) behaviour following a change of prices. Elasticities are able to describe quantitative changes in behaviour; for example, price elasticities could describe the extent to which motorists drive more or less after the introduction of road pricing, while cross elasticities can describe the extent to which people might change their amount of deriving following a change in the attributes of alternative modes. However, elasticities are not able to describe which cognitive or motivational processes are behind these quantitative changes, nor which behavioural adaptation strategies an individual chooses – both of which are necessary to understand and predict user reactions to differentiated pricing.

There are several aspects, which can have consequences for the implementation of a new pricing structure. Firstly, in most situations, mobility behaviour is highly habituated and strongly linked to peoples´ lifestyle. Changes in travel habits may not be possible without changes in daily routines, and this may prove difficult or costly and lead to inflexibility even when conditions change. A second problem is that people have limited mental capacities to process information. These cognitive limitations restrict the degree of complexity that people can deal with and thus the degree of differentiation possible. If the differentiation becomes too complex for individuals to understand, people tend to base their behaviour on heuristics. It appears that different individuals have different abilities to understand complex prices and that this also depends on personal and situational factors. Moreover, motivational aspects have to be seen as constraints on behavioural adaptation to differentiated prices. Thus even if transport users are able to understand a complex pricing system and to predict prices in advance, it does not mean that they are willing to deal with these charges and to adjust their behaviour. In this context, acceptability and disengagement are the most important aspects. Thus, when looking at users' reaction to differentiated pricing, it seems reasonable to consider the question of people's acceptability together with their ability to respond to the price signals.

This chapter aims at presenting and explaining psychological factors, which are potential determinants of the relationships between transport policy provisions and behavioural adaptation of transport end users. (Transport operators are not considered within this report.) Of course, there are many psychological theories and factors which could explain and influence peoples´ reaction towards differentiated prices. Section 3.2.1 focuses on psychological theories on behavioural adaptation and on those psychological constraints which are seen as most relevant. Psychological determinants include cognitive and motivational as well as situational and personal factors. A complete and more precise analysis will follow at a later stage of behavioural analysis in this project. Section 3.2.2 concentrates on empirical evidence that is so far available from other studies and past research concerning traffic user reaction on differentiated prices, but also includes transferable results from other sectors such as telecommunications. The last section 3.3 will give a first theoretical approach and an outlook for further work and analysis within the DIFFERENT project concerning psychological and behavioural theory.

3.2 THE CURRENT SITUATION

3.2.1 OVERVIEW OF RELEVANT PSYCHOLOGICAL THEORY

The relevant determinants of user responses to price differentiation can be exemplified by the popular Stimulus-Organism-Response-Model (SOR) of human behaviour. The SOR-Model describes the relationship between a stimulus, which can be seen as information from the environment and peoples´ reaction on that. The organism is seen as interfering variable that determines the resulting individual behaviour via psychological constraints (Figure 3-1).

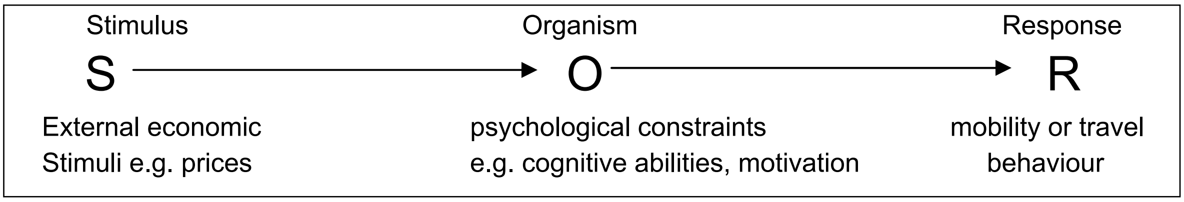

Figure 3-1: The SOR-Model

Stimulus in this case means political instruments like price-policy or the communication of it. The reaction represents mobility or travel behaviour. Within economic theories it is often assumed that the organism-variable is a black box. Thus the user is seen as a rational deciding actor (homo economicus) who shows standardised behaviour and whose attitudes have no influence on choices. But this rational choice approach does not always work. Jacoby & Olson (1977) claim that external economic stimuli, such as prices, do not exert direct effects upon human behaviour. There is no predictable response, because stimuli must first be perceived and interpreted before they can affect decision processes and behaviour. Therefore individual behaviour has to be explained with the help of psychological constraints as it depends on individual perceptions, attitudes, motivations and personality. That means that the organism is no black box. There are psychological determinants in terms of cognitive, motivational, situational and personal factors, which may influence users´ reaction towards transport infrastructure charging.

Table 3.1 shows an overview of identified political, psychological and behavioural aspects concerning differentiated pricing, integrated into the SOR-Model. The analysis of the stimulus – in the case of DIFFERENT the transport infrastructure charges and their implementation – is obviously a very important part of the analysis of the overall problem, but it will not be discussed further in this chapter, as it does not directly relate to psychological aspects. They will be considered at a later stage of behavioural analysis in this project, analysing their relationship with user responses.

Peoples´ reaction to transport infrastructure charging, especially on differentiated pricing systems, is a central aspect of the work within the DIFFERENT project. That is why some basic assumptions and underlying theory referring to behavioural adaptation shall be clarified first. Afterwards there will be four sections presenting briefly the four types of psychological constraints which may determine this behavioural adaptation. Thus the focus is on those determinants which are thought likely to be the most important. The remaining variables will be considered in Deliverable D4.1.

Stimulus	Organism			Response
Transport policy / Key policy inputs	**Cognitive Factors**	**Motivational and Emotional Factors**	**Personal Characteristics and Situational Factors**	**Behavioural Adaptation**
• Price differentiation • Information provision • Availability / Use of aids and advice systems • Price variability • Modus of payment • Competing possibilities and their prices • Enforcement / Penalties • External justification	• Information processing - (price) perception and storage / knowledge - comprehension - mental capacity • Heuristics - anchoring and framing • Cognitive comfort / Psychological costs • Demand on attention • Experiences and Expectations	• Acceptability - Problem perception - Goals - Perceived Effectiveness - Outcome expectations - Perceived fairness - Social norms • Perceived behavioural Control • Disengagement • Habits • Economy • Personal involvement • Perceived infringement on freedom / Reactance • Reference prices • Negative emotions • Trust	• Personality type • Sex • Age • Education • Income • Type of journey • Time pressure	• Higher Decision on Mobility and Driving Behaviour - Residence location - Work location - Leisure activities - Car ownership - Vehicle selection • Mobility Behaviour - Modal choice - Destination choice / Aggregation of destinations - Route choice - Trip frequency / Trip suppression - Change in distance - Change in timing - Ride sharing / Car Pooling - Compliance rate (errors / violations) • Driving Behaviour - Style of driving - Speed choice

Table 3.1: Overview of political, psychological and behavioural aspects of differentiated pricing

Behavioural adaptation

Behavioural adaptation occurs as users respond to changes in the transport system. However, there are some premises that have to be fulfilled so that a change of behaviour can occur (OECD, 1990):

- The traveller must be able to perceive the change, although the perception does not have to be conscious.
- The traveller must have the possibility to change their behaviour.
- The traveller must have the motivation to change their behaviour.

Differentiated pricing is increasingly applied to manage the user's demand for infrastructure capacity. But therefore it is necessary to understand and predict not just quantitative but also qualitative user reactions towards differentiated pricing in order to manage mobility. Important dimensions of mobility and driving behaviour are general aspects of transport use like mode choice, length of trip, route choice, time of driving, trip frequency or style of driving. Thus, congestion for instance is mainly determined by the time of driving, route choice and style of driving (steady driving and a homogeneous flow of traffic decreases the probability of congestion). There are various options that people actually employ to reduce their car use; for example, trip chaining, changes in mode choice and departure time etc. As travel behaviour is strongly linked to people's lifestyle, changes in the transport system might influence not only these daily routines but also higher level decisions such as vehicle selection, leisure activities and choice of residence (Gärling et al., 2002). Therefore a differentiation has to be made between behavioural adaptation, that refers to short-term, medium-term or long-term decisions. The hierarchical structure of mobility behaviour (Schlag, Schade & Risser, in press) describes these three relevant decision and behaviour levels (Figure 3-2).

	Behaviour level	Behaviour Content	Environment	Time horizon
I	Higher level decisions with consequences on mobility and driving behaviour	- Residence choice - Workplace choice - Leisure activities - Car ownership - Vehicle selection	Space structure, land use, road network, Traffic supply	long-term (reflected)
II	Mobility behaviour	- Mode choice - Trip frequency - Route choice - Length of trip - Time of driving		medium-term (routinized)
III	Driving behaviour	- Style of driving - Speed choice - Etc.	Driving situation	short-term (automatized)

Figure 3-2: Hierarchical structure of mobility behaviour (Schlag et al., in press)

The top level includes long-term (life-style) decisions which do not directly concern mobility behaviour but which both affect, and are affected by, this behaviour. They include decisions on place of residence or place of work and therefore on spatial relations that have to be managed in future. Decisions on car ownership or on the type of car also belong to this level. Decisions at this stage are made infrequently and with some care: they may have long-term consequences and tend to constrain decisions at the lower levels. The medium-term level of mobility behaviour includes mode choice and other decisions which directly affect traffic participation. These decisions refer to concrete trips and to intentions that will influence driving behaviour. The third level describes the short-term aspects of concrete driving behaviour.

Decisions at the first and second level have underlying habits and are thus hard to change. Higher order life-style decisions can create objective constraints, whereas habituation on mobility behaviour causes subjective constraints, which are seen as unchangeable. Driving behaviour is characterised by strong preferred habits which are supported by automatisms. Thus we see impediments to changes in mobility behaviour on all levels as they are associated with high costs.

But if behavioural changes become necessary, an adaptation occurs normally according to the “cost minimization principle” (Loukopoulos, 2005). This principle states that people are unwilling to change their basic routines as a result of economic incentives or prices. They prefer the status quo as in other areas of life as well. If changes are necessary, they will be kept as small as possible. “As small as possible” means that people want to maintain the present activity schedule (Gärling et al., 2002). Thus, the type of strategy chosen will depend on the “psychological costs” associated with it. A wide range of adaptation alternatives including, for example, more efficient car use, suppressing trips, and switching travel mode are considered. These adaptation alternatives are argued to be implemented sequentially over time according to the cost-minimisation principle beginning first with the less costly and effective alternatives. The cost minimisation hierarchy may vary according to trip purpose. For instance, for work trips it might be easier to switch mode in order to maintain the activity schedule whereas for shopping or leisure trips other strategies such as trip chaining or changing destination will be seen as more appropriate.

Cognitive factors

Research in cognitive psychology already provides knowledge about the cognitive limits of users faced with a differentiated charging scheme. Thus the perception and the knowledge of prices play an important role in users´ reactions. Whether a person can understand a pricing system and its communication depends on their prior knowledge and experiences. Experience with principles of differentiated charging in various domains of life may enhance people’s understanding and acceptance of these principles in transport. But it also could be that these experiences are domain-specific and hardly transferable. For example, the introduction of yield management pricing by rail operators in e.g. Germany was met with heavy opposition, while airlines use these principles successfully for years. However, it is not clear yet how experience influence user reactions. Furthermore there is always the question on cost of behavioural adaptation. Costs in this context include financial costs, but also psychological effort required to process the relevant information and change behaviour. Thus, the higher these psychological costs, the less likely a change in travel behaviour as a reaction to differentiated charging becomes. Processing lots of information is also restricted by people’s limited attention span and mental capacity to process information.

For the purpose of attempting to understand consumer reactions to prices, the short-term memory (STM) and long-term memory (LTM) systems and their respective capabilities are the most critical aspects as both systems have a strong effect on the processes by which consumers acquire and use information such as prices (Jacoby & Olson, 1977). The LTM contains a seemingly unlimited number of symbols representing all stimuli in permanent storage. In contrast the STM system has a severely limited information storage capacity and there is a decay of symbols, if one does not rehearse the information. That means that people are able to process only a certain amount of information at a time. When people are provided with too much and too complex information (information flooding/overload), as might be the case with highly differentiated prices, capacity is exceeded and consumers become overstrained. This may lead to poorer decisions (Engel, 1990).

Mental capacity is often described in terms of chunks, which represents a grouping or combination of information that can be processed as a unit. Referring to the limits of people’s capacity for processing information, Miller (1956) has shown that the extent of memory capacity amounts to between 5 and 9 chunks. Too many dimensions in price differentiation would make the pricing system too complex, i.e. people would not be able to deal with all the information and would therefore be unable to understand it and adjust their behaviour accordingly.

If the differentiation becomes too complex for individuals to understand, people tend to base their behaviour on a simplified mental model of the price structure. In contrast to systematic processing of information, the use of such heuristics is a more limited processing mode that demands much less cognitive effort and capacity. There people focus on available information that enables them to use simple rules to formulate their judgements and decisions. This entails only minimal amounts of data collection and analysis. Heuristics are cognitive strategies which are often described as rules of thumb. These mental shortcuts are quite useful as they reduce complex problem solving tasks to more simple judgmental operations, but also allow for a much greater chance of error. The results are suboptimal decisions, which represent the price of simplification.

Homburg and Koschate (2005) suppose that people prefer the heuristic processing as it means less effort. Heuristics will be used depending on the personal relevance or importance of the problem, the time and cognitive resources available and whether the heuristics seem likely to lead to the decision intended. The more important a decision is the less heuristics will be used, but if resources are limited, heuristic strategies may be adopted.

Kahnemann, Slovic and Tversky (1991) have investigated several heuristics used in making decisions. For example, availability heuristics involve judgements on the basis of the most easily accessed relevant information. Heuristics related to availability are anchoring and framing. The framing heuristic implies that the selection of an option is influenced by the way the options are presented; an option can either be framed positively as gain or negatively as loss. Small but certain gains are generally preferred over larger but uncertain gains, while large but uncertain losses are generally preferred over smaller but certain losses (Sternberg, 1996). The ‘adjustment-from-an-anchor’ heuristic describes the common human tendency to rely heavily (to “anchor”) on one trait or piece for information when making decisions.

Another problem is cognitive comfort. This refers to psychological costs in terms of transaction costs and concerns the effort required to process complex information. People tend to object to highly differentiated price structures as processing complex information tends to put them off, because they are cognitive misers who do not want to waste effort. This means that they will be looking for ways to economise on their mental effort and, where possible, will tend to rely on heuristics. This is for example obvious in the telecommunication sector, where people often prefer fixed charges (Bonsall et al., 2004).

Motivational factors

Even if a differentiated charging system is designed in a way that people would be able to understand it, they may not be willing to do so. Therefore, apart from the cognitive aspects, a central motivational factor that might influence user reaction toward differentiated pricing is acceptability. If users do not accept the system, they may not make an effort to understand it. In such cases they may not change their behaviour to the extent they could, or may even resist making any change (consumer resistance to Deutsche Bahn AG’s new fare system may be an example of this).

The definition of “acceptance” and “acceptability” should be clarified at this stage. In some definitions “to accept” is described as “to give an affirmative reply to something” (Hornby & Growther, 1995). Elsewhere it is described as “to respond/react favourably to”. But one has to distinguish between attitudes and behaviour. Eagly & Chaiken (1993) define attitude as “a psychological tendency that is expressed by evaluating a particular entity with some degree of favour or disfavour”. In terms of attitudes “acceptance” would be defined as an affirmative attitude towards an specific object like infrastructure charging. In terms of behaviour “acceptance” could be defined as a behaviour which corresponds to the aims and objectives of the system to be implemented. To prevent inaccuracy of terms the concept of “acceptability” was introduced. Acceptability refers to the (affirmative) attitude towards a specific object. Therefore it is more hypothetical, whereas “acceptance” is related to some kind of behaviour as an (re-) action towards an object. Attitudes are relevant before the measure is introduced, i.e. when people are unfamiliar with the proposed concepts. When the measure is introduced, there is the assumption that the previous attitudes, among other things, guide peoples´ behaviour. In this investigation we will concentrate on attitudes and hence on “acceptability”.

Within the heuristic model of acceptability by Schlag et al. (1998) several factors have been identified which contribute to the acceptability of transport pricing measures. For the evaluation of such pricing systems the most relevant issues of acceptability seem to be:

- Problem perception
- Personal Goals

- Perceived effectiveness
- Perceived fairness
- Social norms.

The perception of traffic-related problems is a necessary precondition for regarding problem-solving measures as important (Steg & Vlek, 1997). It is assumed that high problem awareness will lead to increased willingness to accept solutions for the perceived problems.

There are different general aims connected to transport pricing measures (e.g. financial aims, ecological aims, demand management, etc.). On the other hand, travellers as well as others pursue certain mobility aims. The potential conflict between these perhaps different aims is crucial for the question of acceptability. The problem is that, in principle, a large number of competitive aims and interests are imaginable. Derived from the concept of "social dilemma" social vs. personal aims are distinguished (Dawes, 1980). In the case of road pricing it is to be expected that a higher valuation of common social aims will be positively related to acceptability of the charge, while pursuing personal and gain maximising aims may lead to a rejection of road pricing, because of a threatening restriction of personally important aims (cf. Jaensirisak, 2001; Schade & Schlag, 2000).

If someone recognises traffic problems and their consequences (problem perception), and identifies at least in part the aims of changing these problems (reducing traffic congestion, declining environmental damage, etc.), he or she has to answer the crucial question, of whether the proposed measures are of appropriate effectiveness. Effectiveness refers to the degree to which the aims of the measure can be reached. Lower scores in perceived effectiveness usually correlate with lower acceptability of the particular measure and vice versa. Unfortunately, the factors defining the direction of this relationship are not yet known (cf. Bartley, 1995).

When discussing the introduction of road pricing measures, arguments often arise which question the fairness of such a system (Teubel, 2000). From a psychological point of view, perceived justice or fairness are important prerequisites of acceptability. Justice, as people perceive it, may differ from objective distribution of costs and benefits but surely depends on it as one major parameter influencing personal perceptions. And, as with most personally mediated perceptions, it differs not only between different situations (intra-individual variance) but also between people in the same situation and even between people with comparable objective costs and benefits (inter-individual variance). Therefore, in addition to rational cost–benefit calculations, additional variables influencing the personal cost–benefit ratio must be taken into account. If fairness is tentatively operationalised as personal outcome expectations (cf. Viegas, 2001), it is expected that the more people/respondents perceive advantages following the introduction of transport infrastructure use charges, the more they will be willing to accept it.

Perceived social norms and perceived social pressure refer to perceived opinions of significant others (family, friends) multiplied by the importance of the others´ opinions for the individual (cf. Ajzen, 1991). More precisely, social norms refer to the respondent's assumption about whether his significant others would think that he should accept the strategy. These normative beliefs are concerned with the likelihood that important referent individuals or groups approve of performing a given behaviour. Thus, the more favourable the perceived social norm is with respect to a presented pricing strategy, the more acceptable should the strategy be to that individual.

The influence of acceptability on user reactions on prices will become even more important in the near future, when people will have access to electronic assistance systems which will be able to calculate even the most highly differentiated prices. In this case, user reactions will be less determined by restrictions in cognitive capacity, but even more by the attitude towards the price- and assistance systems including issues such as fairness, trust or social norms.

As described above, acceptability is strongly related to the willingness of users to deal with differentiated pricing systems. The complexity of such a charging system has an impact on user engagement and therefore on user reaction.

Bonsall et al. (2006) found out that a significant proportion of consumers 'disengage', if they perceive cost structures to be too complex. This disengagement sometimes leads them to delay the decision, avoid purchase, opt for the simplest or least uncertain option (if there are alternatives), or just pay up regardless. The qualitative evidence suggests that a proportion of the population would respond to complex road charges by disengaging. This disengagement will sometimes take the form of paying the charge irrespective of its size, and sometimes deciding to adopt an option which avoids exposure to the charge. This could have profound implications for the performance of road pricing schemes and for the structure of models used to predict behavioural responses.

Personal and situational factors

Inter-individual differences in the ability of dealing with complex information are due in part to cognitive abilities, but the user's age, gender and education have to be taken into account when analysing consumer reaction on differentiated prices. Concerning elasticities it is often claimed that travellers with higher incomes tend to be less price sensitive than lower-income travellers (for example, Litman (2006) states that real income as well as age have a positive and statistically significant effect on mileage). However, income does not seem to affect the effort a person is willing to take to estimate costs of a trip (Bonsall et al., 2006). Qualitative research by Bonsall et al. (2006) has suggested that there are a number of "behavioural types" with different attitudes, preferences and behaviours, which are reflected via gender more than income. This is a very interesting result. In interviews the existence of three personality types was discussed: "determined/confident", "cautious", and "trusting". 'Determined/Confident' people always try to get the best deal by spending time looking at different options and exploiting the opportunities provided by complex or highly differentiated price structures. 'Cautious' people wanted a good deal, but were not able or not prepared to spend time ensuring they got one. They might shop around to an extent, but go for something simple, because they were put off by complexity. 'Trusting' people took what was on offer, because they did not feel they could assess what was available or did not feel it was worth the effort. Some of these respondents characterised themselves as 'lazy', whilst others lacked confidence in their ability to judge deals. As mentioned before the distribution of the three types seems to be related to gender. Males were more likely to want to get the best deal, whereas females were more likely to be happy to take things on trust. But there was no effect for income. In psychological research, income is often seen as being related to acceptability, but Schade (2005) found no direct impact of income on acceptability. The desired level of awareness of expenditure varies between people of different income, gender and age and differences also exist regarding the preferred payment method.

Peoples´ ability to understand complex pricing systems depends further on situational aspects such as the time available to deal with relevant information. If people are pressed for time when trying to find out an optimal decision on mobility behaviour regarding the price and their aims, they will have difficulties to process all relevant information to make a good choice. In this case they tend to use heuristics again. Another very important situational aspect is the type of the intended journey as trips range in their value; emergency-, commuting- or major shopping-trips are higher-value trips and therefore inflexible even when conditions change.

3.2.2 AVAILABLE EVIDENCE

Most organisations responsible for the supply of services recognise that they can operate more efficiently, if they can influence the pattern of demand to match their ability to supply the service. The use of price differentiation is an obvious means to achieve this end. Thus the use of peak premiums, or off-peak discounts, is long established in the electricity supply, telecommunications and public transport industries. As in the case of road pricing, theory would suggest that dynamic variations in price might be used to fine-tune the demand hour by hour and even minute by minute and, at least in the case of telecommunications, there is no technical reason why this should not be done. And yet, most pricing regimes are relatively simple and there are few, if any, examples of fully dynamic pricing. Indeed there is distinct trend, notably in the mobile phone and internet markets, towards customers being offered a completely unmetered service where a single lump-sum payment buys unlimited access at any time of day or night.

Research (Nahata et al, 1999; Szabo,1999) suggests that the additional effort required of the consumer to calculate prices is treated by them as a "transaction cost" and that this may explain the popularity of fixed charges in lieu of usage pricing in a wide variety of markets (buffet meals, local telephone service in the US, flat fares throughout the New York City and Moscow subway systems, the Eurail pass, employer-provided family health care premiums that are independent of family size and amount consumed, Disneyland entry fees).

Examples from the telecommunications and utilities sectors

Most suppliers of phone and internet services seem to have concluded that the ability to influence the pattern of demand over time can be an unaffordable luxury in a competitive market. Customers have a preference for simple price structures, or perhaps more accurately, for predictable expenditures, and market share is gained by those prepared to offer this. Exceptional decisions, such as that by AOL in the 1990s, to withdraw, or not to offer, fixed-price packages generally reflect operational problems caused by excessive peak-time consumption rather than an assessment that they are not popular with customers (Nahata et al, 1999; Odlyzko, 2001).

The fact that a supplier may offer a wide range of tariff options is not necessarily inconsistent with their perception of a general preference for simple structures or predictable prices (AARP Research, 2004 ; Glazer et al, 2001) – rather it reflects the recognition that different types of user will prefer different price and service packages reflecting their personal pattern of consumption or their personal preference for fixed versus variable prices. It is interesting to note, however, that although some suppliers, particularly those who already have a large market share, emphasise in their marketing material that customers can choose the package that most suits them, others, particularly new entrants, offer a single simple tariff and emphasise this simplicity in their marketing material. These organisations have clearly recognised that customers are generally put off by the prospect of complex tariff structures.

Research within the telecommunications industries has suggested that customers are rarely very accurate in their estimate of call charges – often overestimating the price of a given call by up to a factor of three (Ovum, 1998). The research also reveals that many, if not most, customers are not sure which tariff would be most advantageous to them and that a substantial minority have consciously chosen to opt for simplicity while recognising that they might not be getting the cheapest deal (FDS International Ltd, 2001). A significant number of mobile phone users apparently tend to rely on word of mouth rather than thorough analysis when choosing a tariff package. The decision to think about changing from one package to another tends to be triggered by some external factor, most usually the need to buy a new handset, rather than by something specifically to do with the price (Gutteridge, 2004).

Similarly, within the utility sectors there is a tendency for a significant number of customers to remain with the supplier they have always had and not switch despite wide publicity for the benefits of switching. One reason for this behaviour is that people find it hard to understand the differences in tariffs charged by different companies and, even if they could understand them, they are unwilling to spend the time making the necessary comparative calculations (OFGEM, 2001a). This behaviour is again consistent with the notion that their choices are conditioned by search costs or transaction costs.

Examples from the Public Transport sector

The public's general preference for simplicity and predictability of prices clearly limits the extent to which, in a competitive market such as telecommunication, suppliers can seek to use variable prices to influence the pattern of demand. But what of the transport sector, where suppliers may have a virtual monopoly?

Two high-profile attempts to introduce variable pricing in the transport sector were defeated by adverse public opinion; the capacity related discounts and advance booking incentives introduced by the German rail operator Deutsche Bahn in 2003, and the yield management pricing introduced by the French rail operator SNCF. Public objection was in each case based on the supposed unfairness of the new pricing regime and its failure to achieve its stated objectives (Seidel et al, 2004). It was suggested that the complexity of the pricing structure and uncertainty as to the availability of tickets made it difficult or impossible for would-be travellers to plan their journeys effectively. This complaint was broadened to include wider accusations of management failure (Deutsche Bahn's supposed failure to operate its trains to timetable, and SNCF's problems with its booking software which led to spectacular own goals such as the widely publicised occasion on which a train was sent out empty because no tickets had been sold due to a glitch in the software) (Rothengatter, 2004).

The problem of perceived unfairness is strongly related to public acceptability. Acceptability is an important precondition for the successful implementation of pricing strategies. However, empirical findings have shown that the acceptability of such strategies is low. Until now economists have been looking for reasons for this refusal by analysing first of all socio-economic characteristics of the drivers concerned. But it is doubtful whether these alone have high explanatory value. Based on a heuristic acceptability model, different determinants of the acceptability of road pricing strategies are identified and analysed in more detail. Concerning the factors influencing the degree of acceptability the analyses showed that in particular the variables “social norm”, “personal outcome expectations” and the “perceived effectiveness” are positively related to the acceptability of pricing strategies. These variables account for nearly 40% of the criterion variance and thus can explain acceptability of such measures much better than the socio-economic variables included (Schade & Schlag, 2003). Schade (2005) has shown a clear correlation between acceptability and the different traffic-related behavioural intentions, but further research is necessary to make clear predictions of behaviour related to acceptability.

The accusation of unfairness in the SNCF and Deutsche Bahn cases is interesting, because it has not featured in the discussion of peak pricing in the telecommunications or utilities industries. The concept of fairness does not seem to arise in the context of competitive markets, presumably because the public know that they can always change their supplier, but it is interesting that peak/off peak differentials in tariffs set by monopolistic suppliers of telecommunications or electricity services have not, apparently, let to accusations of unfairness. Perhaps the key question is whether the peak/off peak differential was perceived as an off-peak discount or a peak surcharge. In the two transport examples quoted above, it seems that the differentiation was seen as an unfair penalty on those who were unable to book ahead or avoid using the peak rate services. This point has obvious implications for the introduction of congestion-related charges for road use.

It seems that, in the two rail examples quoted above, the accusation of unfairness was linked in some way to the question of complexity – that it was unreasonable to expect travellers to be able to work out when to travel, what type of ticket to purchase, or which service to use so as to avoid the perceived price penalties. This complaint about complexity is echoed in the frequent criticism of rail ticket pricing in the UK - two thirds of the individual customers consulted recently as part of the Strategic Rail Authority’s policy consultation on fare structures in the UK rail industry said that fare complexity was a major problem (SRA, 2003). Some potential customers are apparently so concerned that they do not know how to secure the best deal, or avoid paying more than need to, that they avoid using the mode at all. Even though some of the behaviour may be misconstrued – it may be that the complexity of the fares is quoted, post hoc, as an excuse for not travelling by train, rather than being a real cause of the behaviour – it is clear that, for some people at least, the complexity of the fares makes the service less attractive than it otherwise would be. As in the case of the people who opt for simple telecommunication tariffs even when they could save money by doing otherwise, it seems that price complicity is adding a transaction cost (or disutility).

The apparent success of Virgin Trains’ new ticket pricing policy is interesting in this context; customers have apparently welcomed the company’s simplification of the fare structure by designating different services as peak or off peak and removing the former complication (which is still prevalent in rail pricing practice elsewhere in the UK) whereby the price of one leg of a journey depended on whether it was part of a return journey and, if so, when that return journey might be made (Cavanagh, 2004).

The approach to pricing of airline tickets is perhaps unique in the transport sector; the price of these tickets can change, without warning, from one minute to the next and the customers cannot be sure of the price until they purchase their ticket. Uncertainty of this sort might be thought inappropriate in the context of international travel and yet the public do not complain – indeed they seem happy with the thought that they are getting a good deal, even if the price is not at its lowest. They seem to understand that the prices will be higher when the demand is high and that, unless they book well in advance and avoid the most popular services, they are unlikely to get the keenest prices. It appears that the negative connotations of uncertainty in prices is offset, or perhaps does not even apply, when the prices on offer are very attractive or when it is relatively easy, in this case via the internet, to access information about the current price of a given service.

The use of time-of-day pricing via off-peak fares is now the norm in public transport in the UK and is broadly accepted by passengers. However, the US experience of time-of-day pricing in the bus industry has been disappointing; thirty-three US transit agencies introduced time of day pricing between 1970 and 1983 but, within a few years, only three of these had increased the differential, nineteen had allowed inflation to reduce the real value of the differential and eleven had been discontinued. The main reasons for abandonment were, apparently, loss of revenue, fare disputes and failure to achieve the hoped-for shift in demand into the off-peak (Cervero, 1984; Glazer et al, 2001).

The cost of using metered taxis, which are generally considered to be a form of public transport, is interesting in the current context, because the precise cost of the ride is not known to the customer at the point at which they commit to making the journey. The actual cost may depend on the distance and the time taken, (which will depend on the route taken by the driver and the conditions met on that route) and may vary according to the time of day or night, whether particular administrative boundaries are crossed and whether “extras”, such as a charge for carriage of luggage, are added. Unsurprisingly perhaps, previous research suggests that, except in the case of regular journeys, most people have only a very approximate idea of what a taxi journey is likely to cost them (Toner, 2004). Although this uncertainty dissuades some potential passengers, others seem content to trust that the cost will be within reasonable limits and are prepared to commit to the expenditure without knowing what it will be.

Examples of tolls and charges applied to motorists

Thus far, evidence has been drawn from sectors other than private motoring, but this sector does, of course, provide several examples worldwide of prices which vary over time and which some people might regard as unpredictable. Two interesting examples come from Singapore. The first is the road user charge levied electronically on vehicles using the central area (Chin, 2002). This charge varies by time of day and, with up to 12 separate charge bands between 0730 and 0930, is significantly more variable than that which had been applied during the previous, low-tech, area licensing scheme. Prior to its implementation, there was a concern that this degree of variation would lead to confusion but, after a short period during which people became accustomed to the fact that they would need to make sure their watches were showing the right time, the public response to the new system has been favourable. The public also seem to accept, perhaps even to welcome, the fact that the tariff rates and differentials are subject to periodic review in the light of changes in the pattern of congestion.

The other example from Singapore is the pricing of vehicle registration permits. The price of these permits, which effectively control the number of vehicles in use on Singapore’s roads, reflects current supply and demand – the government determines the monthly supply (n) in the light of recent congestion data and people wanting a permit indicate the maximum they are prepared to pay – the actual price is then determined by the nth highest bid. Thus a would-be car owner is faced with uncertainty as to whether he will get a permit at all and about the price he will have to pay. Despite these uncertainties the system has apparently been accepted by the Singaporeans as fair, logical and necessary (Chin, 2004). But the question is how it might be received in a country less used to strong government intervention in the citizens’ day to day business.

The introduction of peak period surcharges on motorway tolls in France and the US provides some very interesting case studies. In 1996 the French motorway concessionaire, Cofiroute, introduced time-differentiated tolls on its motorways near Paris. The charge structure, which was designed to help spread the peak post-weekend flow of traffic back into Paris, included four different time bands between 1300 on Sundays and 1300 on Mondays. The system was not liked by the public who regarded it as unfair, ineffective and unnecessarily complicated. The accusation of complexity was made even though there were only four time bands (Mesqui, 2004). The scheme was withdrawn following public protests and a concern about behavioural responses on the feeder roads (excessive speeding by drivers seeking to get there before rate increases and cluttering up of toll plazas by drivers waiting for cheaper rate periods to begin). A simpler scheme, introduced by a different concessionaire, which is implemented on the A1 and A26 motorways to the North East of Paris on days when particularly heavy congestion is forecast, has not stirred such antagonism.

Holguin-Veras et al (2005) report that a third of truckers who regularly use the New York New Jersey Port Authority's toll facilities were unaware that there were any discounts for off-peak usage and only 2% were aware of the discount for night time usage. We do not know whether this ignorance was due to poor publicity or a lack of interest by the truckers; and even if it is down to the truckers, we do not know whether their lack of interest reflects a disinclination to think about differential charges or a rational conviction that their usage of the toll facility is so time-constrained that discounts for usage at other times of day would be of no possible relevance to them. Nevertheless, it is clear that part of the reason for the failure of differential pricing to achieve behavioural change may be that, for one reason or another, the existence of discounts may not be widely known.

The US experience of value pricing and HOT (High Occupancy Toll) lanes suggests that, if differential charges can yield more reliable journey times, the existence of time-varying charges is not a serious issue for individual motorists. Although there are several examples of peak period charges the two most interesting case studies are from California: the I-15 in San Diego (Supernak et al, 2001) and the SR91 in Orange County (Sullivan, 2000).

The I-15 HOT lane was introduced in 1996 as two tidal toll lanes running alongside an existing toll-free highway. Since 1998 the tolls have been varied dynamically in the light of the expected level of congestion (being kept just high enough to dissuade sufficient users to ensure that the HOT lanes are kept congestion free). Current tolls are clearly posted so that people can make an informed choice before deciding to enter the lane and, although the toll might change again before the motorist has left the lane, the lower rate will be charged. Although the tariffs are variable (changing as often as every 6 minutes) and unpredictable from one day to the next, and although the aim of a congestion-free journey is not always achieved, the scheme has been welcomed by motorists and its success has led to it being extended to 4 lanes over 22 miles. The unpredictability of HOT lane charges (and the complexity of the underlying formula) have not attracted widespread opposition from private motorists since the scheme was launched, and it is suggested that the fact that the individual driver has a choice (to continue in the all-vehicle lane) has been an important factor in defusing criticism (Sullivan, 2001; Supernak et al, 2001; Wilbur Smith Associates, 2002; Eliasson and Lundberg, 2003 and Lindsey, 2003). The scheme organisers do, however, receive a lot of complaints, if the billing system makes a mistake or if the expected level of service in the HOT lane fails to be provided (e.g. if, due to a system failure, the price is set too low or if drivers have been charged and then see traffic flowing quite freely on the parallel freeway) (Supernak, 2004). Interestingly, there is evidence that drivers have come to associate high prices in the toll lanes with congestion on the parallel-running highway and that some drivers are choosing to use the toll lanes only when their price is high (Barton, 2004); this is a logical response by drivers who have a particular aversion to delays and congestion but must complicate the calibration of price elasticity curves. Another interesting result is that, in contrast to private motorists, some businesses do not welcome the uncertainty of their monthly bill for HOT lane usage and express a preference for the previous system of fixed charge peak-period passes (Supernak, 2004; Sullivan, 2004). This difference in attitude may reflect the fact that businesses cannot control their exposure to HOT lane charges as readily as individual motorists.

The SR91 HOT lanes opened in 1995 as a privately built and operational HOT lane facility comprising 4 lanes for transponder-equipped vehicles in the median of an existing 8 lane highway (Sullivan, 2001). The tolls vary according to a pre-published schedule which currently has up to 11 different charge bands on a single day. This level of complexity has been phased in as the operators, with experience, learned how to fine tune the demand and is apparently quite readily accepted by those who use the lanes (Sullivan, 2004). Any antipathy towards the complexity of the tariff schedule is apparently offset by the fact that the toll lanes offer a good level of service even during peak periods and that, ultimately, the motorist can choose whether or not to pay for that service (Sullivan, 2001).

3.3 CONCLUSION

It is clear that people do not always react "rationally" to complex prices. Although there are examples where people show an ability to understand moderately complex pricing signals, they appear to have a general preference for simple and predictable prices and there are also many examples where they even appear unwilling or unable to engage with pricing signals that are only moderately complex. Work within DIFFERENT will need to focus on the circumstances and factors which affect peoples´

ability and or willingness to engage with differentiated pricing of the kind which might theoretically be beneficial in the transport sector.

The degree of differentiation implied by first–best pricing may prove to be too complex for people to deal with and behavioural adaptation to differentiated prices is likely to be constrained by cognitive, motivational, personal or situational factors. The most important questions are:

- Up to what degree of complexity, and in what circumstances, are people able and willing to understand and to respond to differentiated charging structures?
- What psychological factors determine the relationship between price differentiation and user reaction?

A first theoretical approach regarding this is illustrated in Figure 3-3.

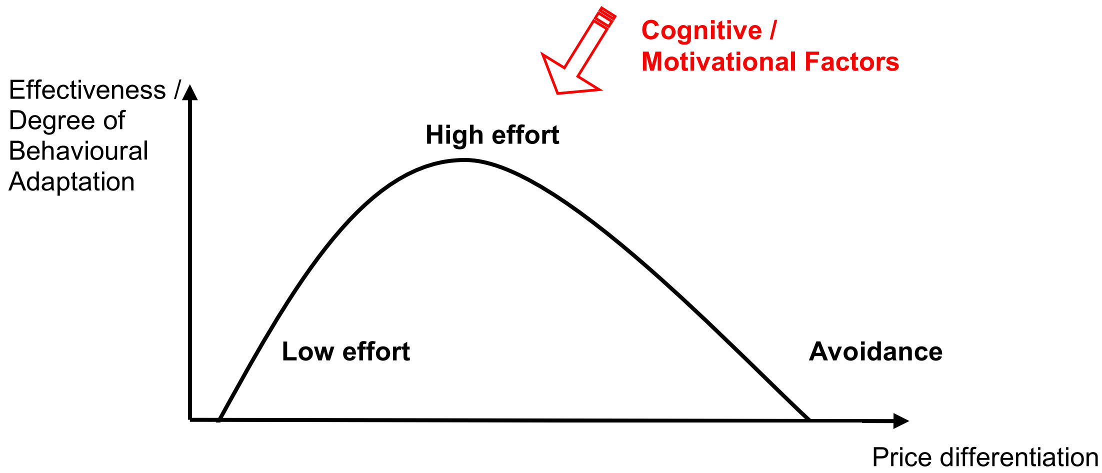

Figure 3-3: Relationship between behavioural adaptation and price differentiation

A non-linear relationship between the effectiveness of a pricing system (the degree of behavioural adaptation) and the price differentiation is assumed. There is a point, beyond which, the more differentiated and complex a price structure, the less behavioural adaptation will occur. This relationship is in line with the effort people are ready to expend dealing with the new pricing system and is influenced by cognitive, motivational and situational factors.

Evidence so far suggests the cognitive capacities of individuals and the acceptability of the pricing regime play particularly important roles, because they constrain the ability as well as the willingness to process complex information on highly differentiated pricing systems.

Within the DIFFERENT project this theoretical approach and the related questions shall be addressed by analysing theoretical and empirical knowledge concerning the identified psychological factors which may have an impact on user reaction towards differentiated pricing. This theoretical analysis shall lead to the formulation of hypotheses about peoples´ respond to complex pricing systems. As there is very little empirical evidence, and since much of that which exists is controversial, it will be quite difficult to compose clear hypotheses on every aspect. It is therefore necessary to prioritise research questions to be explored within the DIFFERENT project. The analysis of case studies and/or the implementation of small experiments will clearly be required to allow an empirical analysis of the theoretical approach.

4 EXISTING CHARGING STRUCTURES

4.1 INTRODUCTION

The present chapter reviews charge differentiation criteria currently in use for transport infrastructure. The aim is twofold:

1. to provide an overview of existing charging differentiation criteria across Europe, whose application is currently under way without considering hypothesis of future changes in their structure and fields of implementation;
2. to give insights about past changes and possible developments in infrastructure charging practices.

The review covers all four modes: road, rail, air and maritime transport. For road transport, a further distinction is made between motorways and urban roads. There are also cases where user charges are levied on roads outside urban areas other than motorways, mainly in the form of bridge or tunnel tolls, and in the special case of Switzerland through a national network-wide charging scheme' but, in accordance with the DIFFERENT work programme, these roads fall outside the scope of this project.

The geographical scope of the review covers the EU 27 level (the 25 Member States + Norway and Switzerland). There is an intrinsic difficulty in providing a summary of charging practices at country level, because charges may differ internally according to specific site characteristics, e.g. a given type of urban area, port, or specific stretch of network etc. In order to avoid an excessive level of detail, the focus is on the "representative" charging practice by each type of infrastructure in a given country, to be understood as the most frequent or common charging scheme applied in a given context.

The number and the complexity of parameters represent the key factors for assessing the degree of differentiation of a given charging scheme. In principle, the presence of more parameters related to a given criteria is in itself an indication of higher differentiation. For each type of infrastructure, the subchapters 4.2.1- 4.2.5 discuss some basic issues like charge description, level of implementation, institutional background and underlying principles.

Table 4.6 summarises the charging differentiation criteria. They have been marked in bold characters, followed by the related parameters, when available. The distinction between criteria and parameters is important to the extent that a given charging criteria, e.g. a landing charge for airport infrastructure use or a user charges for goods vehicles > 12 t for road infrastructure use, may be further specified through different parameters, e.g. the maximum take-off weight and/or the night time surcharge for airport, and the emission classes and/or vehicle number of axis for road.

Section 4.3 draws some conclusions about trends, patterns and future development.

4.2 CURRENT SITUATION BY TYPE OF INFRASTRUCTURE

4.2.1 MOTORWAYS

Current practice in price differentiation is reviewed with reference to the two basic options to build, operate and finance motorways in Europe:

1. to establish concessions and to rely on tolls, and
2. to rely on taxation/public budgets and have the national motorway system administrated as a whole by a state owned enterprise.

In motorway concession regimes, all vehicles categories are subject to distance based charges. Toll rates are determined to contribute to finance the total cost, including investment and return on investment for the concessionaire. Tolls are currently levied on some 20.000 km of motorway networks mainly located in Southern Europe. Countries that historically relied on toll collection to fund motorway development include France, Italy, Portugal and Spain. More recently, also Greece, Croatia and Slovenia have chosen to levy tolls to fund the development of their national motorway networks. In closed tolled motorway links, each vehicle is identified (either visually or electronically) as it passes trough a toll plaza and then charged (either manually or electronically) as a function of vehicle attribute, distance between entry and exit plazas. On the European tolled motorways, the average proportion of revenue generated by cars and Heavy Goods Vehicles (HGV) is 80% and 20% respectively. In countries where different motorway links are operated by several concessionaires - as in Italy (25) or France (14) – inter-company remote payment procedures have progressively developed on a national basis (TELEPASS in Italy, T.I.S. in France and Via Verde in Portugal) to enable motorway users to pay without requiring vehicles to stop using the same payment means regardless which company is operating the link and what charges are levied. At European level, positions and interests of tolled motorway concessionaires (114 organisations in 14 countries) are represented by ASECAP.

Since 1995, in most European countries whose motorway development has been traditionally funded through public budgets, the purchase of a permit (vignette) has been made mandatory for both domestic and international vehicles "having a maximum permissible gross laden weight of no less than 12 tonnes". So far, only Austria and Germany have joined Switzerland in the decision of levying infrastructure charges on heavy vehicles as a function of mileage performed on the national motorway system (all interurban roads in Switzerland), while maintaining other fiscal instruments for cars: taxation on fuel and time based user charges (vignette). In all the three countries, a new generation of Electronic Fee Collection systems (EFC) has been implemented to levy distance based charges without requiring vehicles to stop, as well as to recognise different vehicle attributes.

The European Community framework for motorway tolling in Europe

At European level, rules for road infrastructure charges in both types of context are specified in Directive 2006/38/EC, which amends the 1999 'Eurovignette' Directive 1999/62/EC. The new regime allows (but not obliges) the Member States to levy user charges or tolls on the entire road network and set the rules for price for vehicles over 3,5 t on the TEN-R network.

The so-called 'Eurovignette' Directive was adopted in the year 1999 to complement the creation of a single market for road haulage with a framework to harmonise fixed taxes and infrastructure fees levied in various countries. While ruling that tolls and user charges[6] may not discriminate on the ground of nationality of the haulier or origin/destination of the vehicle, the Directive specifies:

- the type of network – motorway or dual carriageway roads specially designed and built for motor traffic – where tolls can be levied on all motorised vehicles and user charges can be levied on good vehicles that are registered in a different country than the one where the trip is undertaken;
- criteria for determining tolls i.e. the payment of a specific amount for a vehicle travelling the distance between two points of the infrastructure.

The EU regulation specifies criteria for toll determination that are financial in nature (cost recovery). In particular, it specifies that the weighted average toll shall be related to the cost of constructing, operating and developing the infrastructure network concerned. The weighted average toll may also include a return on capital or profit margin based on market conditions. In the absence of a Community framework for tolled motorway concessions, the notion of weighted average tolls is a rather broad umbrella for the variety of approaches used in different Member States to determine tolls.

As recently amended (Directive 2006/38/EC), Community regulation for motorway charges covers both the definition of tolls and the range for their differentiation. The amount of tolls shall be based on distance travelled between two points on the infrastructure and the type of vehicle classified by:

- weight (<3,5 t; >3,5 t and <12 t; >12t);

[6] 'Toll' means a specified amount payable for a vehicle travelling a given distance on a section for infrastructure and the amount is based on the distance travelled. 'User Charge' means when the payment confers the right for a vehicle to use the infrastructure for a given period time.

- number of axles (2, 3, 4 or more);
- dimension;
- damage caused to road infrastructure (Annex IV Directive 2006/38/EC);
- Class of emission (EURO 0; EURO I; EURO II; EURO III; EURO IV and less polluting).

Without prejudice to the weighted average tolls, tolls can be varied in accordance to vehicle's emission standard and period of the day provided that the toll is not more than

- 100% (it was 50% in the previous Directive 1999/62) above the toll charged for equivalent vehicles with the strictest emission standard;
- 100% above the toll charged during the cheapest period of the day.

In either case, fine tuning of tolls must be proportional to the objective such measures aim to achieve. In adoption of the principle of subsidiarity, provisions of Directive 1999/62 were already specifying that the Directive "shall not prevent" a Member State from

- extending tolls and users charges to other sections of the primary road network where there are safety reasons for doing so or in the absence of a coherent network of dual motorway/dual carriageway;
- applying regulatory charges specifically designed to combat time and place related congestion;
- attributing a percentage of revenue from tolls and access charges to environmental .protection and balanced development of transport networks.

The revision of the 'Eurovignette' Directive has been prepared during a two years' negotiation process. The old directive was updated with the twofold aim of creating a uniform platform for motorway tolling in the EU and giving further incentives to improve capacity use and environmental performance in the road transport sector. In addition to the reduction of the minimum weight from 12,5 to 3,5 tonnes, main changes introduced by Directive 2006/38/EC make reference to the calculation of infrastructure costs and to their possible differentiation.

1. ***Stricter rules for the calculation of infrastructure costs and their allocation to vehicle categories***. The benchmark of pricing is the weighted average costs of the infrastructure, where costs include capital costs (depreciation and interest on capital), structural repair and current costs of operation and maintenance. Calculation of capital costs is only allowed for new infrastructure (age less than 30 years); exceptions from this rule have to be demonstrated by the Member States. Calculation of tolls shall be based on actual or forecast heavy good vehicles' share of vehicles/km adjusted. If they are based on forecasts, mechanisms must be provided to correct any under or over recovery of costs due to forecasting errors. For new concession companies (i.e. companies established after the transposition of the Directive), the maximum level of toll shall be equivalent to the level that would have resulted from the use of a methodology based on core calculation principles of the Directive. Tolling arrangements already in place shall not be subject to the obligations set out in the Directive for as long as these arrangements remain in force and provided that they are not substantially modified
2. ***Toll differentiation***. For infrastructure in mountainous regions a mark-up may be added to the toll of specific road sections, which are subject to either acute congestion affecting the movement of vehicles, or the use of which by vehicles is the cause of environmental damage. The mark-up may not exceed 25%. Discounts may be given to frequent users, not exceeding 12% of the standard toll. Unjustified disadvantages to non-regular users should be avoided.

National practice in toll determination and differentiation

Waiting for the transposition of amendments to Directive 1999/62/EC, Member States acted in various manners. On 1 January 2004, Austria introduced the 'LKW-Maut', a tolling system for >3,5t vehicles, based on DSRC technology, whose fees differentiated by number of axles. The system covers the entire motorway network and other roads. A similar situation exists in Germany, which introduced 'LKW-Maut' on 1 January 2005, but only for motorways, for vehicles >12 t, and based on GPS-GPRS technology; German fees are determined by emission class and number of axles.

Other countries like Belgium, Denmark, Luxembourg, The Netherlands and Sweden operate a Eurovignette system (user charge) differentiated by number of axles and emission class. In Great Britain, differentiation in prices is based on the time of day: on the M6 the day toll (06:00-23:00) is different to the night one (23:00-06:00). In the ASECAP (http://www.asecap.com) countries like France, Spain, Greece, Italy and Portugal, parts of the motorway network are tolled for all vehicles, and the criterion of differentiation is the number of axles. Cars are included in only one class (number of axles=1).

Appendix 1 reports the situation of Member States with reference to existing status, planned interventions, additional opportunities allowed by Directive (the data are drawn from "A Price Worth Paying - A guide to the new EU rules for road tolls for lorries" T&E 06/1 published by the European Federation for Transport and the Environment).

4.2.2 URBAN ROADS

The review of differentiation criteria of urban road charges is based on charges actually implemented, without reference to demonstrations and experiments whose definitive implementation at large scale is still uncertain or delayed. For example, a long series of past and on-going RTD European projects, e.g. CURAÇAO, CIVITAS, CUPID, PROGRESS, EUROPRICE, etc, have involved a network of cities running several demonstrations of urban charging schemes, e.g. cordon/distance charges in Genoa, Bristol, Helsinki, Gothenburg, etc, but their full integration in urban policies is still not under way. Hence, results and insights from such projects have not been included in the present review.

The only exceptions are the city of La Valletta, whose implementation of city area access charges scheme, reported in Table 4.6, is planned to be operative in the near future (by January 2007) and the city of Milan, whose implementation of the "pollution charge" will start in February 2007 as an experimental phase, and from October 2007 as a permanent measure.

The following types of charging schemes are the ones relevant in the urban context:

1. Access charges (access charges and cordon charges), regulating the access to urban areas or particular zones - usually city inner areas; and Area charges, in which people not subjected to exemptions are charged for driving inside a specific area, including residents (even if subjected to substantial discounts as in London);
2. Parking charges, i.e. charging for the use of urban public spaces, widely adopted in Europe (in practice all the major urban areas use forms of parking charges schemes);
3. Charges for the use of public transport in the form of buses and trams, as well as off-road systems in the form of metros and sub-urban trains;
4. Premiums for car insurance, which in more recent schemes relate directly to infrastructure usage.

Table 4.6 only lists the first type of schemes, since charges for parking and public transport do not show marked differences between different European countries. Similarly, the advanced car insurance schemes - as far as they exist yet - do not differ much from each other.

Access and area charges

The most prominent of all urban charging systems worldwide is probably the one in Singapore, which developed through several stages from a simple flat-rate paper permit system to one that now changes in half-hourly intervals.

Within Europe (Table 4.1), urban road user charging was spearheaded by the Norwegian cities, starting with Bergen, Oslo and Trondheim, which were later followed by Kristiansand, Stavanger, Namsos and Tønsberg; Tromsø with its introduction of a petrol tax is a special case that could only be employed where an area is remote from other cities (and therefore form other petrol stations).

City	Type	Purpose	Differentiation
Bergen	Cordon	Road investment	2 vehicle weight classes Concession for vehicles with tags Initially 16/5 then 24/6 (hours per day / days per week)
Oslo	Cordon	Initially mainly road investment, now only public transport	2 vehicle weight classes 24/7
Trondheim	Initially cordon, then zonal system, then added inner city cordon, now discontinued	Initially mainly road investment, later also public transport and traffic management	2 vehicle weight classes Initially 11/5, then 12/5 then 12/7
Kristiansand	Cordon	Mainly road investment	2 vehicle weight classes 24/7
Stavanger	Zonal system	Mainly road investment, but also public transport, walking and cycling	2 vehicle weight classes Concession for vehicles with tags Initially 12/5, then 24/7
Rome	Cordon	Traffic reduction, better enforcement of access control	Permits available only to selected user groups; residents exempt 6.30 - 18:00 Mon-Fri and 14:00 - 18:00 Sat in Central Rome; 23:00- 03:00 Fri-Sat in Trastevere
Durham	Single point access	Environmental improvements	6/6
London	Area charge	Congestion reduction, public transport investment, improved reliability of journey times, improved efficiency of distribution of goods and services	Series of exemptions Concessions for residents 11.5/5
Tromsø	Petrol tax	First mainly road investment, then public transport and environmental improvements	n/a
Namsos	Cordon	Road investment	Ceiling of number of payments per month 12/5
Tønsberg	Cordon	Traffic calming	2 weight classes Concession for vehicles with tags 24/7
Milan	Access charge	Curbing pollutant emissions	Vehicle emissions classes 7:00-18.00 Mon-Fri Discounts for residents
Florence	Entry permits	Traffic reduction, better enforcement of access control	Daily permits for visitors pre-booked in hotels within the zone; annual permits at much reduced price available only for special user groups 24/7
Stockholm	Cordon	Traffic reduction, environmental improvements	Series of exemptions Highly differentiated by time period 12/5
Maribor	Access charge	Traffic reduction, environmental improvements	Type of vehicle (delivery vehicles exceeding 3.500 kg, delivery vehicles up to 3.500 kg)

Table 4.1: Overview of Area and Access Charges in Europe

The rationale behind the first schemes was to raise revenue for road or bridge construction projects and, accordingly, there was no need to consider differentiated charges. Heavy goods vehicles were generally charged higher, and in some cities there is a simple distinction between day (system on) and night (system off), while others do not even apply that simple distinction, but charge 24 hours per day, seven days per week.

In Norway, as well in the other European countries where urban road user charging was being considered, the motivation behind this moved away from infrastructure financing to traffic and congestion reduction – hence the re-branding as ‘congestion charge’ - and the resulting improvements in environmental conditions. This then led also to increased considerations of targeting the charge at areas, times and special user groups, where charging would be most effective to meet its overall objective.

One result of this that in the most recent charging schemes that apply to all traffic, i.e. in London and Stockholm, an entire range of vehicles received exemptions for all those user categories that are deemed to be desirable (buses, low emission vehicles) or essential for the social and economic function of the city (emergency services, public utilities). Motorbikes are generally exempt, albeit less for political reasons rather then practicality, since their number plates are very difficult to recognise with electronic means for enforcement purposes.

The Stockholm congestion charge, which went through a full scale trial from 3 January to 31 July 2006, was the most highly differentiated in Europe yet, since, quite apart from the range of exemptions, it varies the level of charge in accordance with the level of traffic in time slots that go as low as 30 minutes (Table 4.2).

A referendum on the system’s future was held on 17 September and, although more than 60% of Stockholm residents were against the scheme before the start of the trials, a majority of residents within the city supported it in the referendum, while a majority of those in the surrounding area voted against it. As a result of the general election held on the same day, the incoming government was a coalition of centre-right parties, who had opposed the scheme from the outset; but, to the surprise of many, they pledged to go ahead with the full-scale permanent introduction of the scheme, simply due to the fact that its effectiveness in terms of traffic reduction had been overwhelming.

Time interval	Charges (SEK)
06:30 – 07:00	10
07:00 – 07.30	15
07:30 – 08.30	20
08:30 – 09.00	15
09:00 – 15:00	10
15:30 – 16:00	15
16:00 – 17:30	20
17:30 – 18:00	15
18:00 – 18:30	10
18:30 – 06:30	0

Table 4.2: Tariffs for the Stockholm Congestion Charge

The urban charging schemes that are running in Italy so far are a hybrid between ‘general’ road user charging schemes and mere access control. Historically, urban pricing in Italy has been associated with the institution of ZTL (Zones with Limited Traffic), corresponding to limited areas in historical centres in which the access is subjected to a payment for specific vehicle categories (generally freight and commercial vehicles). Currently, in Italy there are 93 municipalities with operative ZTL[7], but in some cases no charge is required with the access to the city centre being only subject to administrative permits released by the local municipality police department. When applied, charges

[7] See LEGAMBIENTE (2006)

differentiation is related to vehicle pollution classes, e.g. in Milan, type of vehicle, time and day of the week.

Parking charges

Parking charges are applied in every single country of the EU27, and generally there is little difference between them. The main differentiation criteria are day of the week (weekday vs Saturday vs Sunday), time of day (day vs night) and city area (generally, the more central and convenient, the more expensive). Convenience also often means that on-street parking is more expensive than off-street parking.

Another differentiation criterion generally adopted in parking charges schemes is the differentiation between residents and non-residents, i.e. the set up of 'Resident Parking Areas', sometimes also referred to as 'Blue Zones', which allow residents a complete or partial exemption from parking charges or even reserve entire street sections for parking by residents only.

One example of a more complex parking charges scheme can be found in the greater Athens Area, where the following distinctions are made:

- Off-street parking in garages, with differentiated charges depending on the location, time of parking and duration (day, month, year, etc) as well as progressive charges where the first hour is much more expensive than subsequent ones (although this seems counterproductive to general transport policy since it favours long-term parking by commuters over short-term parking by shoppers);
- Off-street open air 'Parking Lots', with another set of differentiated charges depending on time of the day;
- Park & Ride schemes, with lower than usual rates (within the relevant area) applied in the off-street park-and-ride garages developed near the Metro Stations by the Metro Operating Company and additional charges beyond these periods;
- On-street parking (applied with limited success so far, due to the lack of systematic police enforcement and limited collection of fines) with a special controlled parking scheme to be introduced by the Municipality of Athens in the Central Business Area, where 5,500 spaces are to be provided in the first phase with 2,500 for residents (at €10 per year), 1,000 for special uses (government etc. mostly free) and 2,000 for short-term parking (up to 3 hours) for visitors at € 0.50 per half hour for the first two hours and € 2.00 per hour for the third hour onwards, but only operating on Wednesdays and Saturdays (which are the main shopping days in the area).

Public transport charges

Charges for the use of public transport vary widely between European countries, and even within countries, with regard to the overall level of charges. Most schemes relate their charges to the type of transport (metros generally the most expensive and buses the cheapest) and the length of the journey, the latter mainly in terms of distance travelled, but in some cases (e.g. in Poland) relating to the expected travel time duration.

Discounts, and in some cases even full exemptions, are generally given to children, students, the elderly and people with a physical handicap, or in the form of weekly, monthly or annual season tickets. Variations by time of day in the form of off-peak discounts, which exist for many trains, are less usual for single tickets in urban forms of public transport; where they exist, they often only apply to holders of season or other special tickets (e.g. on the London Underground). What can be found more frequently are special tariffs for weekends or for night buses.

Insurance schemes

A last category of differentiated charging schemes related to road usage are car insurance premiums, which used to consider only the type of car, the age of the driver and the length of time they drove accident-free. Data from a trial carried out in The Hague will be subject of a DIFFERENT case study, but these schemes are no longer only at a trial stage; they are now being rolled out in several European countries. The latest of these schemes was launched in the UK on 5 October 2006, following a pilot with 5,000 motorists.

This scheme consists of two parts: an up-front premium reflecting the driver's age, driving experience and the car driven (as in traditional insurance schemes); after that the premium will depend on the mileage driven and the roads used (motorways being cheapest), a discount for driving in off-peak hours and, for 18 to 23 year olds, a premium for driving during the high-risk accident time between 23:00 and 6:00[8] Obviously, these schemes apply to all roads and not just to the urban roads which are the focus of this section. Furthermore, they are strictly speaking not charges for infrastructure use, but since they can influence infrastructure use by inducing drivers to use their cars less in favour of public transport they merit inclusion within the DIFFERENT reference framework.

Ideal versus actual differentiation criteria

Table 4.3 which is adapted from on an 'ideal' set of differentiation dimensions suggested by GRACE in their deliverable 2, in which a maximum degree of differentiation would be reached, compares this ideal with the actual situation with regard to urban charges against the currently 'best' existing charging differentiation criteria in urban roads.

Ideal Differentiation Criteria	Actual Criteria Applied			
	Access and Area Charges	Parking Charges	Public Transport Charges	New Insurance Premiums
User characteristics				
➢ Type of vehicle	√	(√)	√	√
➢ Condition of the vehicle				√ (vehicle age)
➢ The way the vehicle is being driven				√
➢ Driver/passenger characteristics	√ (disabled)	√ (disabled)	√	√
Location characteristics				
➢ Road characteristics		√		√
➢ Site environment		√		
➢ General level of traffic volumes	√ (implicit)	√ (implicit)		
Time period				
➢ Current congestion levels	√ (implicit)	√ (implicit)	√ (implicit)	
➢ Accident risk				√
➢ Meteorological conditions				
➢ Sensitivity to noise	- (reverse)			
➢ Site characteristics depending on activities being undertaken		√		

Table 4.3: Ideal versus Actual Differentiation Criteria

Table 4.3 shows that there are big differences between the different types of charging schemes. The vehicle type is the one criterion that is most widely used, albeit to different degrees. Disabled drivers or passengers generally get discounts or concessions, while price differentiation for the young and the elderly only applies for public transport use or for car insurance, generally in terms of discounts for these user groups with the notable exception of young drivers, who already used to pay higher insurance premiums due to their higher accident risk in traditional insurance schemes, but where new technology now –as mentioned above – allows to discourage them in particular to drive at night times through peak premiums. The age of the vehicle played always a role in the determination of insurance costs, while the way in which it is driven could only be taken into account with the emergence of new technologies.

8 The Guardian, 6 October 2006.

Location characteristics are most widespread for the differentiation of parking charges: charges are generally highest in the most central and busiest locations, and in particular for on-street parking in front of rows of shops, where activity dependent time variation also comes in, since charges often only apply during shopping hours. More generally, parking charges tend to be lower for overnight than for daytime parking. For access and area charges, levels of traffic volumes are implicitly accounted for, since they are only introduced where traffic levels are high enough to cause problems, and the revenues are either used to expand infrastructure capacity or to manage demand.

Similarly, for differentiation by time period, there is no scheme yet in operation which reacts directly to changing levels of congestion over the day (this was only trialled in Cambridge during the 1990s), but charges are often highest at times of the day when congestion is expected to be most severe, with Stockholm being the example where this is most apparent. The suggestion made by GRACE to relate charges to noise sensitivity is interesting, but current practise runs into the opposite of what common sense would suggest: noise sensitivity is highest in the night, but with the exception of some of the Norwegian cities, where charging runs 24 hours per day, and the Trastevere district in Rome, where only night charges are used at weekends, charging operates only during daytime hours.

4.2.3 RAIL

Table 4.6 summarises the charging structure for rail infrastructure in the EU (ECMT, 2005). Charging regimes can be distinguished by the following characteristics and each is discussed in more detail below:

- pricing principles adopted (marginal cost pricing, marginal cost pricing with mark-ups, full cost recovery and full cost recovery less state subsidy);
- type of mark-up (if any) (either two-part tariffs or mark-ups on the variable component);
- type of variable charging (e.g. by train-km or gross t-km);
- charges for different elements of cost (e.g. maintenance, renewal and environmental).

Principles

Marginal cost pricing is usually advocated in order to encourage efficient use of the railway network. However railways tend to exhibit economies of density and so the marginal cost of extra network utilisation is below the average cost. Thus full cost recovery is not achieved through (simple) marginal cost pricing. Therefore, two broad pricing principles can be distinguished; pricing by marginal cost (MC) and pricing to recover full cost (FC) (usually through some average cost pricing scheme). There are two further pricing principles reported in the following table, marginal cost plus pricing (MC+) and pricing to recover full cost less government grants (FC-). Both MC+ and FC- are aimed at full cost recovery less government grants, however the MC+ approach, being based on marginal cost pricing, is viewed as less distorting in terms of incentives. Table 4.4 shows which principles are applied in the different countries.

Country	Pricing principles
Austria	MC+
Belgium	FC-
Czech Republic	MC+
Denmark	MC+
Estonia	FC
Finland	MC+
France	MC+
Germany	FC-
Hungary	FC
Italy	FC- (Traffic management only)
Latvia	FC
Netherlands	MC
Poland	FC
Portugal	MC
Romania	FC
Slovenia	FC
Sweden	MC+
Switzerland	MC+
UK	MC+

Table 4.4: Rail charging principles in Europe

Type of mark-up

There are two kinds of mark-up used in charging MC+ pricing; a mark-up on the variable charge and/or a separate fixed charge (not related to actual usage). Where mark-ups on variable charges are implemented, economic theory states that the least distorting method of doing this is to inversely relate the proportionate mark-up on marginal cost to the elasticity of demand for each user group (Ramsey pricing). A separate fixed charge is an example of a two part tariff. This has the advantage that once an operator has decided to enter the market, he pays only marginal costs, that is, incentives to act efficiently are not distorted unless the fixed part of the tariff is prohibitive of the operator entering the market.

Type of variable charge

As well as the proportion of revenue collected by actual usage charges differing between European countries, there are also differences in what unit of usage is used as the basis for charging. A mixture of number of train-km, gross tonne km and train path km is used by systems in Europe. In terms of charging marginal cost, the unit of usage should reflect the driver of the marginal damage caused to the network. Therefore to reflect different cost drivers (and, as is likely, to reflect distributional concerns) a mixture of charging measures have been implemented.

Elements of costs charged

Across Europe elements of maintenance, renewals, train planning and operations, congestion and scarcity, accidents and environmental costs are used as the cost base to determine both marginal cost (in the MC and MC+ approaches) and average cost (in the FC and FC- approaches). No country charges for all of these categories and only Switzerland, Germany and France charge for 4 of these categories. All except Italy charge for maintenance expenditure and 13 out of 18 countries charge for train planning and operations. Charges for congestion and scarcity, accidents and environment are only undertaken by a minority of countries.

Acceptability of railway pricing reforms

Work has identified five major stakeholders important for acceptability: i) railway infrastructure managers, ii) train operators, iii) passengers, iv) policy makers and governmental bodies, and v) the business community e.g., freight forwarders and shippers. Train operators will, argues Adler et al. (2002), be the most impacted by the proposed pricing strategy

Table 4.5 summarises the acceptability barriers for all groups of stakeholders identified in the analysis.

Stakeholder Group	Barriers to Acceptability
Infrastructure Operators	Applicability of the pricing strategy
	Effectiveness/efficiency of the pricing strategy
	Risk of losing part of the market share of a specific truck or railroad terminal
	Use of pricing strategy revenues
Policy Makers	Political cost
	Effectiveness/efficiency of the proposed pricing strategy
	Applicability of the proposed pricing strategy
Train Operators	The extent of effectiveness/efficiency of the proposed pricing strategy
	Risk of losing part of the market share due to the increase in competition
	The level of charges imposed
	The use of the revenues deriving from increased charges (e.g. possible redistribution in the form of railway investments/capacity and service expansion)
	Perception of equity of measures/discriminatory practices against particular user groups (e.g. small operators)

Source: Adler et al., 2002

Table 4.5: Acceptability barriers to marginal cost based pricing strategies for railways

4.2.4 AIRPORTS

Airports are infrastructures with a multi-product nature. Many different services and activities are conducted, with commercial services becoming more important day by day.[9] Actually, airport activities can be divided in three groups: operational, handling and commercial (Doganis, 1992). Alternatively, the first two are usually considered as aeronautical services whilst commercial activities are regarded as non-aeronautical.

The fare structure at any airport is parallel to such a classification and by any means complex. When referring to operational activities the following charges can be mentioned: landing charge, passenger charge, freight charge, parking charge, security charge, and so on. A similar myriad of charges is found for handling or even commercial services. Such structure may vary slightly when paying attention to a particular airport, though the basic structure is always the same and based on International Civil Aviation Organization recommendations (ICAO, 1991). For example the landing charge should be non-discriminatory and based on the maximum take off weight (MTOW). Nevertheless, and quite probably the main novelty on airport charges during the last decade has to do with environmental charges (noise and pollution) that try to put into practice the ‘polluters pay’ principle.

Therefore the question of differentiation can be analysed for a range of airport charges, although most studies have focused their attention on the aeronautical side.[10]

9 Airports may generate more than 60% of their income from concession activities (Zhang and Zhang, 2003)
10 It is worth mentioning here that landing charges only constitute about 5 percent (on average) of total costs for a single scheduled European flight. Still, total airport costs can constitute more than 20 percent of total costs.

For airports in Europe, a review of infrastructure charges based on information collected from internet sources and from the GRACE project[11] was conducted. Airport differentiation criteria are reported in Table 4.6 for a sample composed by main airports in each country according to number of passengers. Smaller airports are not analysed, though in general the fare structure and differentiation criteria is usually quite similar to other larger airports in the same country.[12] The review identifies the following main differentiation criteria:

- Weight of the vehicle, which can be related either to the maximum take-off weight (in the majority of cases) or to the maximum take off mass. In practice, all airports examined in the review use the weight of the vehicle as differentiation criteria.
- Noise of vehicle, in the majority of big airports and in airports nearby urban areas.
- Time of landing, according to which landing and noise emissions are surcharged during night in several airports.
- Emission charges, only applied in London Heathrow, Stockholm Arlanda, Gatwick and Zurich.
- Several discounts are applied to domestic flights and training aircraft, e.g. Larnaca, Copenhagen, Vilnius.
- Peak/off peak traffic conditions are considered only in few cases, i.e. Vienna, Helsinki/Vantaa and in UK airports London Heathrow, Gatwick and Manchester Intl.

DIFFERENT also focuses mainly on aeronautical charges, and in particular on those charges that are more frequently subject to differentiation criteria. Quite probably the best known and, in many cases subject to differentiation criteria in itself, is the landing charge[13]. This is a charge that tries to recover the cost of airport runway provision and maintenance[14]. According to ICAO recommendations, this charge should be based on the aircraft maximum take off weight (or mass), and consequently it appears as such for all airports in our sample. Another criterion to charge for landing might be the type of route, usually discriminating against flights connecting with non EU airports (e.g. in the case of Spain) or offering discounted charges for domestic flights or even training aircraft.

Another important differentiation criterion relates to airport externalities, namely noise and air pollution. As a matter of fact, noise has been given a more extensive treatment than air pollution around the airport so far, though the prospects are that more emphasis will be put on air pollution and consequently on emission charges in the future[15]. It should be noted, however, that the treatment of aircraft air pollution at upper levels of the atmosphere is not considered at the airport; this might be treated through other mechanisms as the European Commission and Parliament are considering at the moment[16]; a comprehensive treatment is being advocated in order to reduce the climate change impact of aviation. Several proposals are of interest, in particular:

1. Introduction of a tax on kerosene at least for domestic and intra EU flights with possible exemptions for carriers on routes that compete with non EU carriers. This tax is already on application for domestic flights in the Netherlands.
2. Introduction of and Emission Trading System (ETS) for airlines markets.[17] Such a system is already in place for other industries and would constitute an important precedent from which to draw lessons in the case of air transport.
3. Promotion of research on bio-fuels for aviation.

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11 Deliverable 2 of GRACE. This project presents with more details the current practice at airports.

12 A possible exception to this might be the so called “low cost” airports that are nowadays increasing their share of movements and passengers in Europe.

13 Many airlines claim that there should be a shift towards a decrease share of airport fixed charges (e.g. landing charge) and an increase share of flexible charges (e.g. passenger charge) that could be used to cover the same costs that are actually covered by fixed charges.

14 The usual reference for landing charge calculation is the average cost incurred.

15 This charge depends on the volume and quality of aircrafts emissions, as levels of CO_2, NO_X, etc.

16 Communication from the Commission on reducing the climate change impact of aviation (COM, 2005, 459 final) and European Parliament resolution of July 2006 (TA-0296/2006)

17 Directive 2003/87 established the European Emission Trading Scheme (EU ETS) affecting 12.000 energy intensive installations.

4. Air Traffic Control improvements and promotion of a Single European Sky[18].

Nevertheless the establishment of emission charges has not been ruled out completely, and in the future they might be even compatible with an Emission Trading Scheme.

At airports the impact of aircraft noise has been traditionally attenuated through command and control measures, as ICAO also advises. Specifically, the 33rd ICAO Assembly in 2001 introduced the concept of a "Balanced Approach" to noise management[19]. This consists of identifying the noise problem at an airport and subsequently analysing the various measures available to reduce noise through the exploration of four principal elements: reduction of noise at source (i.e. less noisy airplanes); land use planning and management; noise abatement operational procedures (e.g. use of preferential runways) and operating restrictions.

Although the ICAO Balanced Approach to noise management does not specifically consider the setting of noise charges, this institution recognizes that airports with serious noise problems may need to implement them. In fact, the ICAO Airport Economic Manual ICAO (1991) states that noise related charges, if implemented, should stick to the following principles:

- They should be levied only at airports experiencing noise problems and should be designed to recover no more than the costs applied to their alleviation or prevention (insulation schemes, monitoring)[20].
- Any noise-related charges should be associated with the landing fee, possibly by means of surcharges or rebates, and should take into account the noise certification provisions of Annex 16 of the Convention on International Civil Aviation in respect of aircraft noise levels. (The effective perceived noise level EPNL of the aircraft concerned could be used as a charging or rebating parameter).
- Noise related charges should be non-discriminatory between users and not be established at such levels as to be prohibitively high for the operation of certain aircraft.

Further, ICAO recommends taking as a cost basis for noise related charges the cost of noise monitoring and noise abatement measures. No mention is made of noise annoyance or social cost of noise. At this stage, it seems that ICAO recommendations and European Commission advice are quite contradictory (European Commission, 1995), since the Green Paper on Fair and Efficient Pricing states that "prices paid by individual transport users will have to more accurately reflect the full costs of transport", therefore for the problem of noise, such statement implies that full (social) costs of noise should be taken into account when fixing airport charges. However, when coming into practice, this problem has been only partially addressed by the EU[21] so far.

The Commission Communication on Air Transport and the Environment (European Commission, 1999) proposes the use of economic instruments in order to improve the environmental performance of air transport operations. To this end, a proposal for a directive for the purpose of calculating noise charges was prepared by the Commission in 2001[22]. In this proposal, the starting point was the classification of aircraft according to ICAO certification values in EPNL, that are considered to be the most consistent way to reflect the contribution of aircraft to the level of noise exposure around airports. It is also stated that such classification should be sufficiently flexible to allow for the introduction of airport specific elements, such as the fleet mix operating at a given airport, the unit noise charge at departure or arrival, the noise threshold at departure and arrival and the reference period during which the unit noise charge applies. Nevertheless the proposal was not finally approved by the European Parliament and the Council.

[18] This EU initiative seek to promote a more rational organization of European air space, increasing capacity and ensuring high safety standards throughout Europe.
[19] 33rd ICAO Assembly in 2001.
[20] Therefore not the value of external costs.
[21] The importance of the airport noise problem in the EU has led the European Parliament and the Council to produce two Directives 2002/30/EC and 2002/49/EC.
[22] European Commission, (2001). Proposal for a Directive of the European Parliament and the Council on the establishment of a Community framework for noise classification of civil subsonic aircraft for the purpose of calculating noise charges. COM 2001,74 final.

To our knowledge there are no cases of noise charges based on the social cost of noise. This would be a charge that fully internalizes the costs imposed on third parties due to aircraft noise.

The actual practice when dealing with the noise problem through a pricing mechanism is not homogeneous. Several options are possible: creation of a new charge (noise charge), for the differentiation of the landing charge based on this criterion (e.g. Heathrow airport) and/or introduction of surcharges on the landing charge when noise is perceived as most annoying (i.e. night periods). Examples of all these cases are shown in Table 4.6.

Finally, the need to efficiently use capacity has resulted in a small number of airports applying peak pricing mechanisms. The demand of airport infrastructure services does not have a flat profile; on the contrary, it exhibits seasonality, with peaks and off-peak period within the year, the week and the day. Only few airports made use of such alternative, in most cases where a peak appears at a given hour during the day. The wider application of this charging policy is expected to give airlines and passengers a correct signal of airport capacity costs[23].

With reference to our sample of airports, it can be seen that all of them have a landing charge based on the aircraft weight. Less than half have a night time or a noise surcharge (exactly, 46.5%) and no more than 10 per cent have some consideration of peak and off-peak periods (i.e. airports in Austria, Finland and United Kingdom). Similar with regard to emissions charges, with only 4 out of 43 airports analysed having introduced it (i.e. airports in Sweden, United Kingdom and Switzerland).

4.2.5 PORTS

While some ports are to a large extent free to set their charges as they wish, and most notably in the UK, in most cases the state, municipal or regional authority concerned decides port tariffs. Charges in this context refer to fees levied on shipping vehicles in return for their access to a given port. This is not, however, related to the charges imposed for the physical transfer of goods (or passengers) between ship and shore, also known as the 'utility' function of a port, and which tends to be the domain of private actors (e.g. stevedores, terminal operators etc.). Terminal charges therefore relate to port services provided for the most part by private actors, notwithstanding that much of the port infrastructure is leased from public port authorities, some of whom may not apply full cost recovery principles.

The charging practice therefore differs by country and also by port within certain countries, and there is a large range of different charges that are applied. For instance, the main categories of port access charges levied on ships in Rotterdam, which is Europe's largest seaport, are as follows:

- Harbour dues for seagoing vessel;
- Harbour dues for inland vessel;
- Quay dues;
- Buoy dues (for anchoring);
- Waste disposal dues;
- Vessel traffic system (VTS) charge;
- Reporting of vessels charge;
- Pilotage charge;
- Towage charge;
- Mooring and unmooring charge.

[23] Some proposal to develop a secondary market for slots at airports are being analysed by the Commission. If such a system is implemented this could also work as an efficient system to allocate slots based on willingness to pay at peak and off peak periods.

But even this long list is not exhaustive. In addition to the above, charges applied in other European ports can also include:

- Tonnage dues;
- Canal dues;
- Sanitary dues;
- Small-ship dues;
- Ice dues;
- Freight dues;
- Passenger dues;
- Lighthouse dues
- Cargo handling charge (usually by terminal operators).

To some extent the charging regime within ports appears somewhat archaic, reminiscent of a bygone age, and also perhaps to some extent reflecting the natural monopoly positions of seaports in terms of regional and national trade. There appears to be some scope to simplify charging practices, and to consolidate fees into fewer charges; the latter is now a common feature of the UK port system, which has tended to go further in the area of port privatisation than other EU countries.

The combination of a great number of charging categories and a certain level of differentiation in each category leads to a rather differentiated structure of port and port access charges: Ship gross tonnage and cargo type, type of vessel, length of stay, time of stay etc are some criteria that are used widely.

COUNTRY	DIFFERENTIATION CRITERIA				
	Road		Rail	Airport	Ports
	Motorway	Urban roads			
Austria	Toll for vehicles >3,5t: • Vehicle class (axles);	None	Variable charges: • Charges per Gross t-km • Train-km	Airports: Vienna and Salzburg. • Landing charge according to Maximum Take-Off Weight. • Peak/off-peak charge for general aviation (Vienna)	Port dues and other fees: • Ship gross tonnage/cargo type wharfage dues: • Ship gross tonnage/cargo type
Belgium	User charge for vehicles > 12 t: • Emission class • Vehicle class (axles)	None	Variable charges: • Charges per Train-km • Quality of train • Path/service; • Speed of train; • Time of day; • Weight of train.	Airport: Brussels Int. • Landing charge according to Maximum Take-Off Weight • Night time surcharge • Noise Charge.	Port dues and other fees: • Ship gross tonnage/cargo type • Frequency • Ship type • Origin and destination of trade wharfage dues: • Ship gross tonnage/cargo type
Cyprus	None	None	Not existent	Airport: Larnaca. • Landing charge according to Maximum Take-Off Weight • Night time surcharge • Special rates for domestic flights and training aircraft.	Port dues and other fees: • Navigation and vessel dues based on ship gross tonnage Cargo dues: • For use of cranes etc based on cargo
Czech Republic	User charge for all vehicles: • Weight	None	Variable charges: • Charges per Gross t-km • Train-km • Distance travelled Discount charge • New operator • Environmental friendly vehicles	Airports: Brno and Prague. • Landing charge according to Maximum Take-Off Weight • Noise charge (Prague). • Special rates for new additional flights (Prague).	Port dues and other fees: • Ship gross tonnage/cargo type wharfage dues: • Ship gross tonnage/cargo type
Denmark	User charge for vehicles	None	Variable charges:	Airports: Kastrup and Roskilde	Port dues and other fees:

COUNTRY	DIFFERENTIATION CRITERIA				
	Road		Rail	Airport	Ports
	Motorway	Urban roads			
	> 12 t: • Emission class • Vehicle class (axles)		• Train-km • Per bottleneck	• Landing charge according to Maximum Take-Off Weight • Night Noise charge (Kastrup) • Special rates for domestic flights and training aircraft (Roskilde)	• Ship gross tonnage • Ship type • Length of stay • Frequency Cargo dues: • Type of cargo • Type of activity
Estonia	None	None	Variable charges: • Charges per Gross t-km • Train-km Fixed charges	Airport: Tallin. • Landing charge according to Maximum Take-Off Weight	Port dues and other fees: • Based on ship gross tonnage • Ship type • Frequency • Certain Standard compliances
Finland	None	None	Variable charges: • Charges per Gross t-km	Airport: Helsinki/Vantaa. • Landing charge according to Maximum Take-Off Weight. • Night noise charge. • Peak/off-peak charge (minimum landing charges are higher during peak hours).	Port dues and other fees: • Ship gross tonnage • Length of stay • Annual volumes • Type of vessel wharfage dues: • Ship gross tonnage/cargo type • Direction of cargo flow • Type of traffic •
France	Toll for all vehicles: • Vehicle class (axles)	None	Variable charges: • Charges per path-km • Train-km Fixed charges	Airports: Paris/Charles de Gaulle, Paris/Orly and Nice. • Landing charge according to Maximum Take-Off Weight (Mass in Nice). • Noise charge. • Night time surcharge (Charles De Gaulle and Orly).	Port dues and other fees: • Geometric ship volumes, • Type of navigation • Frequency • Volume of activity • ,Type of ship Cargo dues: • Type of cargo

COUNTRY	DIFFERENTIATION CRITERIA				
	Road		Rail	Airport	Ports
	Motorway	Urban roads			
Germany	Toll for vehicles > 12 t: • Vehicle class (axles) • Emission class	None	Variable charges: • Train-km	Airports: Frankfurt Intl, Munich Intl, Berlin/Schönefeld, Sttutgart and Berlin/Tempelhof • Landing charge according to Maximum Take-Off Weight (Mass in Sttutgart). • Night noise charge (Frankfurt Intl). • Noise charge (Munich Intl, Berlin/Schönefeld, Berlin/Tempelhof and Sttutgart). • Type of flight (Munich): passenger or cargo. • Special rates for training aircraft (Berlin/Schönefeld) • Night noise charge (Munich Intl and Berlin/Tempelhof).	Port dues and other fees: • Navigation and vessel dues based on ship gross tonnage – rebates for regular liners • Type of cargo • Length of stay • Ship type Origin and destination of trip
Greece	Toll for all vehicles: • Vehicle class (axles)	None	Currently no charge for rail infrastructure use, but the following are awaiting ministerial approval for 2007: • Train-km • Speed • Weight per axle • Quality of track (signaling, electric traction etc) • Departure time (peak/off peak) • Special issues (dangerous goods transport, electric power consumption)	Airport: Athens Intl • Landing charge according to Maximum Take-Off Weight.	Port dues and other fees: • Ship gross tonnage/cargo type wharfage dues: • Ship gross tonnage/cargo type
Hungary	User charge all vehicles: • Weight	None	Variable charges: Charges per path-km Train-km Type of train	Airport: Budapest Ferihegy Landing charge according to Maximum Take-Off Weight. Noise charge.	Port dues and other fees: Ship gross tonnage/cargo type wharfage dues: Ship gross tonnage/cargo type

COUNTRY	DIFFERENTIATION CRITERIA				
	Road		Rail	Airport	Ports
	Motorway	Urban roads			
			Ancillary services		
Ireland	Toll (3 lnks) for all vehicles: • Vehicle class (axles)	None	No charge for rail infrastructure use (services operated by track owner)	Airport: Dublin airport Landing charge according to Maximum Take-Off Weight.	Port dues and other fees: • Ship gross tonnage • Ship type, • Origin and destination Cargo dues: • cargo type, cargo condition
Italy	Toll for all vehicles: • Vehicle class (axles)	City area access charge (e.g. Parma, Firenze, Roma, Ferrara, Milan, Reggio Emilia, Cesena and Bologna): • Day of week • Time of day • Type of vehicle (freight vehicles, discount or exemption for Electrically Propelled vehicles) • exemption for busses, taxi, NHS vehicles, etc	Variable charges: • Charges per path-km • Train-km • Per node Fixed charges	Airport: Milano Malpensa and Rome Leonardo da Vinci-Fiumicino • Landing charge according to Maximum Take-Off Weight. • Night time surcharge.	Port dues and other fees: • Ship gross tonnage Cargo dues: • Tax on cargo commodity/value/weight
Latvia	None	None	Variable charges: • Train-km • Type of train Discount charge	Airports: Riga and Liepaja • Landing charge according to Maximum Take-Off Weight. • Special rates for training flights.	Port dues and other fees: • Ship type • Based on ship gross tonnage and number of calls/year

COUNTRY	DIFFERENTIATION CRITERIA				
	Road		Rail	Airport	Ports
	Motorway	Urban roads			
			• Freight forwarders	• Night time surcharge (Riga). • Additional charge for landing from 16:30 to 09:00 (Liepaja).	Freight dues: • Tax on cargo commodity/tonnage or per unit
Lithuania	User charge for all vehicles Weight	None	n.a	Airport: Vilnius • Landing charge according to Maximum Take-Off Mass. • Special rates for domestic flights. • Night time surcharge.	Port dues and other fees: • Ship gross tonnage • Type of service • Type of vessel • Frequency • Compliance with certain standards wharfage dues: • Ship gross tonnage/cargo type • Ship type • Cargo dues: • Type of cargo • Volume
Luxembourg	User charge for vehicles > 12 t: • Vehicle class (axles) • Emission class	None	n.a	Airport: Luxembourg: • Landing charge according to Maximum Take-Off Weight. • Night time surcharge.	Port dues and other fees: • Ship gross tonnage/cargo type wharfage dues: • Ship gross tonnage/cargo type
Malta	Not existent	City area access charge (La Valletta, from January 2007) • Day of week • Time of day • exemption for residents, public bus, electric cars, motorcycles, commercial vehicles with	Not existent	Airport: Malta Intl. • Landing charge according to Maximum Take-Off Weight. • Night time surcharge.	Port dues and other fees: • Ship gross tonnage/cargo type wharfage dues: • Ship gross tonnage/cargo type

COUNTRY	DIFFERENTIATION CRITERIA				
	Road		Rail	Airport	Ports
	Motorway	Urban roads			
		regular deliveries			
The Netherlands	User charge for vehicles > 12 t: • Vehicle class (axles) • Emission class	None yet	Variable charges: • Train-km	Airport: Amsterdam Schipol. • Landing charge according to Maximum Take-Off Weight. • Noise charge. • Night time surcharge • Other charges according to type of flight.	Port dues and other fees: • Ship gross tonnage with discount for inland ships • Load of ship • Length over all (LOA) • Frequency • Type of cargo • Compliance with certain standards (negative tariff) • Origin and destination of service Other dues: • VTS and reporting fee based on ship size
Poland	User charge for vehicles > 3,5 t (on A1, A2, A4/A18 toll for all vehicles): • Weight • Vehicle class (axles) • Emission class	None	Variable charges: • Charges per path-km • Train-km	Airports: Warsaw Frederic Chopin, Krakow-John Paul II Intl., Katowice Intl. • Landing charge according to Maximum Take-Off Weight. • Season charge (Katowice Intl.): summer and winter charge. • Night noise charge (Warsaw Frederic Chopin). • Noise charge (Warsaw Frederic Chopin).	Port dues and other fees: • Ship gross tonnage/cargo type • Ship type, frequency wharfage dues: • Ship gross tonnage/cargo type
Portugal	Toll for all vehicles: • Vehicle class (axles)	None	Variable charges: • Train-km • Distance travelled • Speed (freight transport) • Maximum weight per axle (freight vehicles)	Airport: Lisbon. • Landing charge according to Maximum Take-Off Weight. • Out of hours charge.	Port dues and other fees: • Navigation and vessel dues based on ship gross tonnage • Type of ship • Frequency • Type of service • Length of stay Cargo dues: • Cargo type

COUNTRY	DIFFERENTIATION CRITERIA				
	Road		Rail	Airport	Ports
	Motorway	Urban roads			
					• Origin and destination
Slovakia	User charge for all vehicles: • Weight	None	Variable charges: • Train-km • Track category	Airport: Bratislava. • Landing charge according to Maximum Take-Off Weight.	Port dues and other fees: • Ship gross tonnage/cargo type wharfage dues: • Ship gross tonnage/cargo type
Slovenia	Toll for all vehicles: • Vehicle class (axles) • Vehicle height	City area access charge (Maribor) • Type of vehicle (freight vehicles, exemption for residents, disabled, etc)	Variable charges: • Train-km • Type of train • Type of network • Peak off/Peak time	Airport: Ljubljiana. • Landing charge according to Maximum Take-Off Weight.	Port dues and other fees: • Type of cargo Gross Tonnage • Frequency
Spain	Toll for all vehicles: • Vehicle class (axles)	None	Variable charges: • Train-km • Peak off/Peak time • Track category	Airports: all airports. • Landing charge according to Maximum Take-Off Weight. • Differentiation between type of airports and routes. • Special rates for training aircraft. • Out of hours charge.	Port dues and other fees: • Ship gross tonnage/cargo type • Ship type • Frequency • Type of terminal operation • Out of hours charge wharfage dues: • Ship gross tonnage/cargo type
Sweden	User charge for vehicles > 12 t: • Vehicle class (axles) • Emission class	City area usage charge • Day of week • Time of day (peak hour charge) • Type of vehicle • Exemption for busses, taxi, NHS vehicles,	Variable charges: • Charges per Gross t-km	Airport: Stockholm Arlanda. • Landing charge according to Maximum Take-Off Weight • Emissions charge. • Noise charge.	Port dues and other fees: • Vessel dues based on ship gross tonnage • Ship type • Emissions (Gothenburg) • Compliance with certain standards (negative charge) • Type of cargo • Origin and destination

COUNTRY	DIFFERENTIATION CRITERIA				
	Road		Rail	Airport	Ports
	Motorway	Urban roads			
		etc			• Fuel type
United Kingdom	Toll (on M6): • Type of vehicle (car, van, HGV) • Day/Night	City area usage charges: • Day of week • Time of day • Type of vehicle • Type of user	Variable charges: • Train-km • Type of vehicle Fixed charges (franchisees only)	Airports: London Heathrow, Manchester, Gatwick, Aberdeen, Glasgow and Edinburgh. • Landing charge according to Maximum Take-Off Weight. • Noise charge (Heathrow, Manchester and Gatwick). • Peak/off-peak charge (Heathrow, Manchester and Gatwick). • Emissions charge (Heathrow and Gatwick). • Night noise surcharge (Aberdeen, Glasgow and Edinburgh). • Type of flight (Manchester): passenger/cargo.	Port dues and other fees: • Ship gross tonnage/cargo type • Length of stay • Frequency • Ship type Harbour Captain Services: • Assessed on ship gross tonnage • Ship type • Service • Frequency
Switzerland	User charge distanced based for vehicles > 3,5 t: • Maximum laden weight • Emission class	User charge distanced based for vehicles > 3,5 t: • Maximum laden weight • Emission class	Variable charges: • Charges per Gross t-km • Train-km • Per node	Airport: Zürich. • Landing charge according to Maximum Take-Off Weight. • Emission charge. • Noise charge.	Port dues and other fees: • Ship gross tonnage/cargo type wharfage dues: • Ship gross tonnage/cargo type
Norway	Toll for all vehicles: • Vehicle type • Vehicle length	City toll: • Day of week • Times of day • Type of vehicle	Variable charges: • Charges per Gross t-km • Train-km	Airport: Oslo • Landing charge according to Maximum Take-Off Weight. • Night time surcharge.	Port dues, wharfage and other fees: • Ship gross tonnage • Frequency • Length of stay • Frequency • Type of activity Cargo dues: • Cargo type

Table 4.6: Overview of criteria for infrastructure charging differentiation

4.3 CONCLUSION

The brief overview of existing charging differentiation practices in Europe allows the evaluation of two different but interwoven processes: a) the degree of convergence across European countries around specific charging practices and b) the degree of differentiation reached by each charging scheme.

The 'degree of convergence' looks at the level of current harmonization between existing charging practices across European countries.

The 'degree of differentiation' concerns the capability of existing charging differentiation schemes to address the variability of transport conditions, e.g. time, locations, traffic conditions, etc, in order to charge the users at the point of use of the infrastructure by taking account of the full range of externalities.

Table 4.7 shows the current state of the two processes for each infrastructure type as emerged from the review through a qualitative assessment in high, medium and low level.

		DEGREE OF DIFFERENTIATION		
		High	**Medium**	**Low**
DEGREE OF CONVERGENCE	**High**	Motorways		Airport
	Medium		Rail	
	Low	Maritime	Urban Roads	

Table 4.7: Convergence and Differentiation

It can be observed that both the degree of differentiation and the degree of convergence vary horizontally across transport modes and vertically inside each type of infrastructure:

- **Road (Motorways)**: for the use of motorways can benefit of a high degree of convergence across the European countries, i.e. in practice, most European countries charge for part of their motorway network. The degree of differentiation is on average high: all the most important parameters affecting externalities, e.g. type of vehicle, distance travelled, weight, emission class, etc, have been considered in the determination of charge.
- **Maritime infrastructure** charges also display a high degree of differentiation. However, the level of convergence is low in contrast to road transport. The high degree of differentiation originates from the historic development and adaptation process over time of port tariffs. The strong involvement of local, municipal or regional authorities has led to low conversion in maritime transport as national as well as at European level. From the list of drivers affecting externalities for sea ports shown below in Table 4.8, ship gross tonnage and vessel types are considered. Moreover, ports start to consider emission levels based on the bunker fuel and the speed of the vessel when approaching a port.

Externality	Drivers
Port congestion and delays	Demand profile & volume
	Vessel characteristics & operating condition
	Service requirements
	Port capacity (waterside)
	Technological infrastructure
	Personnel training & working experience
	Port operational characteristics (hub)
Accidents	Demand profile & volume
	Driving / manoeuvring behaviour
	Personnel training & working experience
	Port capacity (waterside)

Externality	Drivers
	Vessel operating condition
	Technological infrastructure
Landside pollution	Demand profile & volume
	Traffic patterns (e.g., public transport use)
	Landside accessibility
	Port landside capacity
	Population area
	Port facilities (e.g. landside parking)
	Technological infrastructure
	Vessel characteristics (passenger/car capacity
Air Emissions	Fuel type
	Type of Engine
	Operating speed

Sources: MC-ICAM (2002), Baird and Wilmsmeier (2007), UBA 2006

Table 4.8: Main external cost drivers in ports

- The degree of differentiation and convergence in **rail infrastructure** charging occupies an intermediate position, in the sense that both processes are currently under way. Differentiation charges currently applied consider infrastructure damage (gross t-km), type of train and distance travelled (train-km), which capture important drivers addressing externalities, as can be observed in Table 4.9 below.

Externality	Drivers
Wear and tear costs	Usage related damage
Congestion and delays	High level of capacity utilization
Scarcity	Capacity constraints
Accidents	Exact connection between rail infrastructure use and number & severity of accidents is unknown
Environment	Train and fuel use
	Population living near tracks
	Demand profile & volume

Source: MC-ICAM (2002)

Table 4.9: Main external cost drivers in rail

- However, charges for congestion and scarcity are scarcely levied in rail track access charges in Europe. On the other hand, the process of convergence, even if not completely fulfilled, has been supported by the European Commission through the “Common Transport Policy” and specific Directives[24], aiming at ensuring interoperability and adopting common approaches in charging infrastructure at national level.
- **Urban roads and airport infrastructure** charges show a mixed trend, i.e. a medium degree of differentiation with low convergence (urban roads) and a low degree of differentiation with high convergence (airport).
- Charge differentiation for the use of urban roads has shown over the past years a rapid increase, i.e. from the charge of parking space for deterring the use of urban space (still the most common form of charging) to more sophisticated charging schemes addressing congestion and environment. However, convergence is still slow: congestion charges have only been introduced

[24] Directive 91/440, Directives 2001/12, 2001/13 and 2001/14

in very few cities (London, Stockholm), while access charges for entering in a specific city area are more wide-spread, but still follow different principles in different countries and cities.

- For airports, there is large convergence towards the use of landing charges for recovering the runway provision and maintenance, based on the maximum take-off weight, and, particularly in large airports near urban areas, some convergence towards charges addressing noise and emissions. It should be noted, however, that noise is basically addressed with command and control measures and charging still has a minor role. Furthermore, even less examples can be found with reference to charging congestion and scarcity.

Possible developments

It is widely acknowledged that technology is deemed to play an important role, providing the material basis for a sharp increase in charging differentiation. The future developments of positioning technologies, for example, including combinations of Dedicated Short-range Communication (DSRC) equipment and GPS/GSM approaches, are expected to allow further scope for charge variation. Highly sophisticated OBUs - fitted with maps, GPS devices, cellular technologies for communication and back-office operations - could allow the capture of variations in traffic situation, road infrastructure use, population distribution, etc. GALILEO, the European satellite navigation system, has recently received a new push. All the relevant parameters for a full assessment of external costs and in particular for an effective pricing of congestion could be potentially addressed through the use such technologies.

It is to be expected that technological developments are pervasive and able to affect all transport modes in the same way. Currently, GPS-GSM devices find their main application in the road sector, for instance in the German HGV tolling system that relies on satellite tracking to determine the distance trucks travel on the Autobahn network, while in several countries car insurance premiums are becoming based on distance travelled (through in-vehicle GPS). Electronic charging in urban areas will improve the cost-effectiveness of solutions based on the combination of automatic number plate reading technologies (ANPR) and Radio Frequency Identification Devices, as being experimented in London[25]. Also in the maritime sector, more pollutant ships are being tracked at ports and along the trip in most environmentally sensitive areas (Mediterranean Sea), and GPS devices are also used for real-time communications about rail delays in freight services.

However, it should be stressed that technology in itself is only an enabling factor that need to be supported by other equally important factors. In particular, the following ones deserve to be mentioned:

- Legislative factors, providing a common (European) legislative framework ensuring non-discrimination in the application of charging rules, particularly relevant for transport services with a pan-European playing field, e.g. road freight, for which the existence of common rules is a basic requirement;
- Institutional factors, overcoming the barriers arising from the involvement of different authorities and administration, e.g. transport departments, local authorities, national and European institutions, etc;
- Political problems (acceptability of pricing policies, equity issues, etc), which may hamper the implementation of charging schemes, even if technological solutions would allow them; in particular, the better enforcement of pricing policies allowed by the new technological developments may be stopped by the related problems of privacy violation through the growing use of cameras and tracking technologies.

All in all it can be said that the promising technological developments towards major differentiation in charging practices need to be supported by a multi-faced strategy in order to be fully exploited.

[25] KAPSCH, the Austrian provider of electronic fees collection in London, estimates a reduction by 20% of operating costs incurred by the city administration as result of the implementation of new technological solutions.

5 EXISTING MODELLING APPROACHES

5.1. Introduction

This chapter deals with the capability of existing modelling approaches to simulate the differentiation of tariffs with reference to various modes of transport and at diverse level (urban, strategic, etc.). A brief review of approaches and applications will be presented trying to emphasise the main methodological aspects related to the analysis of differentiation of charges.

More specifically, the chapter will present:

- example applications of the current situation of modelling approaches (on a mode by mode basis);
- a discussion of the capability of the modelling applications presented to simulate differentiation of tariffs;
- conclusions.

5.2. The current situation

5.2.1 Motorway and urban road transport

Concerning modelling tools focused on motorways and urban road transport, several alternative approaches are available. In particular, four approaches are well established[26]:

1. Tactical models (assignment models),
2. Conventional demand/supply interaction models,
3. Integrated land use and transport models (LUTR),
4. Microsimulation models.

Most models of road transport allow travellers to respond to changes in journey time or out-of pocket costs. Usually these two are combined into a "generalised cost" using appropriate values of time.

Tactical models

Tactical models (also referred to as assignment models) are used to simulate path choice of a given pattern of trips (usually road trips) on a given road network. This type of models is therefore focused on a specific problem assuming that several circumstances are given, in particular:

- the origin/destination matrix of trips is fixed: neither origins nor destinations can be changed as effect of the simulation;
- modal split is fixed: road users do not shift on other modes as effect of the simulation.

Tactical models exclude trip generation, distribution and modal split elements[27] and are therefore suitable for evaluating schemes or policies which will only cause local re-routeing of traffic. Typically, these models are developed to analyse interurban corridors (e.g. to forecast traffic on new motorways) or urban areas (the whole city area or city centres.) Different demand segments are usually defined

[26] This classification make reference to the work done in the Fifth Framework Programme research project ISHTAR, Integrated Software for Health, Transport efficiency and Artistic heritage Recovery, Del. 2 "Review of existing transport models and Selection of Models for the ISHTAR Suite", 2002

[27] Note: that there exists a special class of tactical models called "elastic assignment models" which allow the volume of demand in each OD cell to vary in response to changes in the cost associated with that movement. this is done by applying an elasticity parameter which represents all responses other than route choice.

according to vehicle type (e.g. passenger cars, buses, freight vehicles) and different classes of car driver (eg with different incomes) may be represented. Each demand segment will have its own route choice parameters.

Assignment models are appropriate for modelling relatively short finite periods of time. They are often used to model periods when demand is over capacity and when drivers tolerate a certain amount of delay due to congestion, leading to extended journey times. Traffic assignment models are usually applied to examine traffic on a portion of day (e.g. morning peak) - though representation of peak and off-peak periods (in two independent phases) is recommended. Representation of assignment on a daily basis is possible even if more complex.

Several software packages implementing tactical assignment models exist, e.g. CONTRAM, SATURN, DYNAMIT-P, DYNASMART-P.

Conventional demand/supply interaction models

The conventional demand/supply interaction models are characterised by the presence of four components:

1. A trip generation sub-model which estimates the number of trips with origin and destination in each zone using land-use and/or socio-economic data.
2. A trip distribution sub-model estimating where the trips from a particular origin zone are going to (i.e. which is the destination zone).
3. A modal split sub-model which estimates the proportion of trips between each zone by transport mode.
4. An assignment sub-model which allocates trips to particular routes through the transportation system.

Some of these models also represent a fifth choice - choice of departure time – whereby travellers decide, in response to generalised cost changes, to travel in a different time period (e.g. off-peak rather than peak, or at 08:00 rather than at 08:30). It is generally accepted that the positioning of this choice in the sequential series outlined above will vary with journey purpose. It is good practice, when using a demand/supply interaction model, to employ feedback loops to ensure that the final result is in equilibrium but, due to the high computing costs that this may incur, it is common practice to stop short of this ideal.

In conventional demand/supply interaction models, unlike most tactical models, the trip matrix is allowed to vary in response to changes in network conditions (or pricing policies). This step forward in the analysis adds realism to the simulation and widens the range of causes and effects that can be analysed. At the same time, the complexity of the model increases. For instance, even if the focus is on road modes and networks (e.g. a motorway where a defined pricing scheme is implemented), information on alternative non-road modes costs, travel times, observed demand, etc. will be needed.

As for tactical models, different demand segments are identified according to trip purpose (e.g. commuting, personal, etc.) and person type (eg income level) in order to allow for differences in response.

Demand/supply interaction models work at the same scale of tactical models. So interurban corridors are often analysed, while in an urban context, demand/supply interaction models generally cover a whole city or town and are used to evaluate schemes and policies which are expected to have large scale effects over a considerable geographical area. They tend to be used for long term forecasting, perhaps as far as 20 or 30 years ahead.

Among others, software packages implementing demand/supply interaction models are VISUM, EMME/2, MINUTP, TransCAD, DAVISUM.

Integrated land use and transport models

Land Use and Transport models (LUTR) have been developed to take into account that the development of the transport system influences the location decisions of landlords, investors, firms and households. The main characteristic of integrated land use and transport models is that the socio-economic inputs required by a transport model are provided by a land use model, instead of being provided exogenously. Thus, the modelling of the transport side in LUTR models is generally entrusted to a demand/supply interaction model that uses matrices produced by a land-use module (where location and socio-economic activities are simulated). In turn, the transport model calculates a generalised cost of transport, which is fed back into the land use model.

Using a LUTR model, urban road transport is included in a wider perspective as one of the (main) determinants of zone accessibility. Therefore, in addition to transport issues addressed by a conventional demand/supply interaction model, additional questions can be explored, e.g. how transportation improvements or changes in travel costs might, in a perfect market, shift the distribution of residents in an urban area or how a new motorway can affect the location of activities. The price to pay for building this kind of models is that much more data is needed and the effort required to set-up the models is much higher.

A number of integrated urban land use and transport systems are in use today; among the most popular, MEPLAN and TRANUS can be named. They use different theoretical references and modelling techniques. For instance, the measure of accessibility can be an attribute of a specific zone or can be given for each O/D pair. Another significant difference concerns the modelling of location choices: some models are pivoted around interaction between different activities and estimate at the same time locations and trips matrices, while other models include a specific module for location and a separate module for estimating matrix. The former models are more complex to use, but ensure more coherence to results.

Integrated land use transport models differ in their detail (some have very few zones but might include many different types of trips and land uses, others have more zones but might include less disaggregation of trips and land uses). They also differ in respect of the treatment of time; some provide predictions only for a single year, whereas others produce a sequence of predictions showing how an urban area might evolve over time as its land use gradually responds to evolving accessibilities.

Microsimulation models

Microsimulation models are based on three main pillars:

1. the ability to accurately represent any road network geometry;
2. the ability of simulating single vehicles and using behavioural models that can account for drivers' reactions;
3. a dynamic assignment of vehicles on the network.

On the network side, dedicated graphic tools allow the representation of road networks in minute detail, coding of geometric data (length, number of lanes, width of lanes, etc.) including signalling systems (e.g. traffic-lights and their timing) etc. This capability enables microsimulation models to simulate the sensitivity of traffic conditions to supply elements that macro models cannot take into account. For instance, it is possible to analyse the effects of a traffic-lights timing or of vehicles entering motorways from access ramps taking account even of limited peaks of congestion that disappear when the average speed is considered.

Further capabilities of microsimulation models are:

1. Short term forecasting, e.g. use of real-time evaluation of a set of possible interventions following an incident on a motorway, or to predict emissions so that plans which restrict cars entering the city centre can be implemented if the predicted emissions rise above a set level.

2. Providing inputs to car driving simulators. Sophisticated driving simulators are being developed to allow the assessment of many new in-car systems in a totally safe environment. Microsimulation models can be used to provide realistic interactive scenarios for the simulator.

One disadvantage of this capability is that very detailed information is required to design and set up a microsimulation model. This means that the complexity of the model grows exponentially with the scale of the application and, therefore, such models need large computational power for larger networks. Hence, their application has been originally confined to only very limited parts of any network, but, more recently, microsimulation has been also applied to model much larger networks, in particular urban networks with more than one hundred nodes.

Among the software implementing microsimulation models, the most well known are: AIMSUN, VISSIM and PARAMICS.

No simple categorisation of models can be entirely satisfactory because models are constantly being developed which do not fall neatly into any simple category. An example of some relevance to pricing studies is the Bottleneck Model. Bottleneck models are used to represent the performance of critical parts of a network under high demand. These models are similar to microsimulation models in that they pay great regard to the detailed build up and performance of queues but they may be operationalised through a series of mathematical equations rather than via representation of individual vehicles and they may allow for elastic demand. An example would be the model produced by de Palma et al (2002).

Synthesis

With some notable exceptions, the four approaches above can be classified on the basis of the following key characteristics, which are relevant with respect to the analysis of differentiation of road charges on motorways and in urban areas:

- Fixed or variable demand

  Most tactical and microsimulation models assume that pattern of road demand is constant over the modelled period and any simulated measure can affect route choice, but does not change the amount of demand on the origin-destination pairs. On the other hand, in conventional demand/supply interaction models as well as in land use and transport models, the amount and the pattern of road demand can change over time. Therefore, the second group of models allow simulating a wider set of impacts of charge differentiation schemes.

- Modelling of route choice

  Assuming that one of the main effects of motorways tolling and urban road charging schemes is a re-arrangement of routes, the capability of providing a realistic simulation of path choice is a key feature of models. From this point of view, there are three aspects that can make a difference between models. First, assignment algorithms should include congestion effects by relating travel costs to the flow patterns. If there is no capacity restraint, the travel costs are assumed to be constant at all levels of flow, which is of course unrealistic. Second, static models assume that demand (or any other element of the model) is constant over the modelled period, assuming that link flows (and other outputs) are steady. On the other hand, dynamic models allow for time-varying demand, usually by splitting the modelled period into a number of time intervals and generating a trip matrix for each time interval. Third, some models use deterministic methods, where it is assumed that all drivers, in a same group, are identical in their perceptions of travel costs. Stochastic methods, allowing for between-driver variation in travel costs add realism to the simulation. The modelling of route choice is a feature of the specific software used rather than of the modelling approach discussed above. It can be noted however, that microsimulation models are always dynamic models, while currently most of the demand/supply interaction models and of the land use and transport models do not allow simulating time-varying demand.

- Mathematical or simulation based

  Mathematical methods are macroscopic in nature, treating the flow of traffic as if it was a continuous flow. As a consequence, mathematical relations can be written to express the flow continuity conditions and equilibrium or optimality conditions, and the process of finding the assigned flows can be expressed as a formal mathematical optimisation problem. Simulation-based methods, applied in microsimulation models use a microscopic traffic flow, tracking the location and path of each vehicle. They therefore give a more realistic picture of the traffic flow through the network, in that individual vehicles can be tracked and the movements displayed. However, simulation-based methods generally lack any formal proofs of convergence. In principle, segmentation of demand is very important when differentiation schemes are simulated. However, modelling single vehicles does not mean a full segmentation of demand (i.e. in microsimulation models parameters are not defined for each vehicle, but only for class of vehicles), so this aspect can be considered as neutral with respect of the analysis of charging differentiation schemes.

- Modelling whole urban areas or portion of network

  Tactical models, demand/supply interaction models and land use and transport models are conveniently applied to large areas. Microsimulation models can also be set-up only for large networks provided that enough computational power is available. As the analysis of effects of motorways tolls and charges for urban road users often requires comparing the impacts in large parts of the network, it can be said that microsimulation models are more limited from this point of view.

From the review above, it emerges that for simulating the various impacts of a road charging scheme, it is useful to use a modelling tool able to deal with more than route choice. In urban or metropolitan areas, land-use models can be useful to enlarge the perspective of the analysis. When an interurban corridor is considered, land use aspects are less relevant and a demand/supply interaction model can be useful. Therefore, for the ex-ante simulation of impacts of further toll differentiation on the motorway section of the Brenner corridor which will be carried out DIFFERENT in later stages, a demand/supply interaction model will be used, where both passengers and freight demand is simulated.

5.2.2 RAIL TRANSPORT

There is a relatively small amount of literature on forecasting the demand for passenger rail services, as compared with that relating to the forecasting of road passenger traffic. Within the area three broad types of methodology exist:

- Aggregate direct demand models;
- Disaggregate demand models; and
- Mode choice and assignment models

The aim of this section is to describe the main features of each methodology and indicate examples of their use. The examples focus on those that are freely available within the research domain, where as there are further examples of rail models developed within rail companies or consultancies that are subject to confidentiality.

Aggregate direct demand and elasticity models

The approach involves relating the demand for rail travel between two stations in a given period (the dependent variable) to a vector of explanatory variables whose influence on demand is described by a set of model parameters. Whilst the precise functional form of the demand expression varies from study to study, Fowkes et al (2004) identify a range of commonly used explanatory variables including:

- Rail fares – derived from fares manuals or more commonly average revenue estimates;
- Timetable related service quality – derived from timetables and includes in-vehicle time, service frequency, interchange requirement and connection time;
- Access and egress times – derived from analysis of cross sectional data in the definition of station catchment areas;

- Rolling stock quality – the 'unpacking' of rolling stock quality attributes such as comfort, ride quality, cleanliness, availability of toilets, telephones etc. is usually obtained through market research whereas the total effect can be assessed using aggregate ticket sales data;
- Performance - punctuality and reliability indices derived from published sources;
- Competition – the influence of the price and quality of competing modes of transport (car, bus, coach, air);
- Exogenous factors – derived from analysis of cross-sectional data to examine the influence of changes in population demographics, income (GDP) and car ownership on rail demand;
- Time trend - to account for other secular trends; and
- Dummy variables – to account for seasonality or other shocks to the system (e.g. rail privatisation).

Four of the most commonly applied aggregate demand modelling methodologies are:

- the Passenger Demand Forecasting Handbook (PDFH) - This is a manual of advice maintained by the Association of Train Operating Companies in Britain. It provides a framework for the application of elasticities of demand and rail attribute valuation to facilitate forecasts of the aggregate demand response to changes in:
    - fares;
    - journey time, service frequency and interchange;
    - reliability and punctuality;
    - non-timetable related service quality (e.g. rolling stock quality, crowding);
    - new services and station access;
    - competition between operators; and
    - the external environment (e.g. GDP, car ownership, employment, cross modal competition);
- The Rail Industry Framework (RIF) Model - Developed by consultants Steer Davies Gleave, RIF was designed to focus on the effect of external factors on rail demand. The key demand drivers are similar to those identified in the PDFH but are adapted to take better account of the influence of changes in GDP on rail demand by journey purpose and to identify the contribution that changes in car ownership and road congestion have on rail demand.
- MOIRA - Owned and maintained by AEAT, MOIRA again uses the same basic methodology as outlined in the PDFH but provides software to calculate changes in generalised journey time and consequently demand for all O/D pairs following a timetable change; it also allocates ticket revenue between competing operators.
- The LYTHGOE Model - This model is centred on the specification of station catchment areas and competition between stations. It forecasts the share of traffic travelling from a given origin zone to a given destination station via a given origin station as a function of:
    - fare and timetable related service quality of competing origin stations to the destination station;
    - population in zones around origin and destination stations;
    - access times and distances from origin population zones to origin and competitor origin stations;
    - egress times and distances from destination and competitor destination stations to destination population zones; and
    - quality and cost of competing car travel.

Disaggregate demand models

The approach seeks to model individual choice and demand rather than forecasting collective behaviour such as market shares of travel flows. The individual, in making a choice, expresses a preference amongst a set of alternatives which can be explained by their socio-economic characteristics and the attributes of the choice alternatives. The approach is thought to have better theoretical foundations based on the economic theory of the consumer and, as such, the models aim to explain causality rather than simply capture correlations. They can be readily calibrated to either revealed preference (RP) data, stated preference (SP) data or a combination of both.

Many disaggregate demand models have been calibrated but have generally been tailored to a specific task or set of circumstances, and are therefore not readily transferable to other situations. An exception to this is the PRAISE (Privatised Rail Services) model which was developed at the Institute for Transport Studies, University of Leeds to look at the potential for open access competition following the privatisation of rail services. The model was initially developed to assess competition on the Leeds to London corridor but it has subsequently been applied to other routes in the UK and elsewhere.

PRAISE has, more recently, been re-written and developed on behalf of the UK Strategic Rail Authority as a Windows software package capable of assessing demand and costs for small networks of stations incorporating the services of up to 5 operators, each with 10 different ticket types. The software comprises:

- a hierarchical disaggregate demand model, the lower level of which forecasts market shares for each service and ticket combination, with the upper level allowing for the rail market to expand or contract according to the overall level of service. The model is also able to forecast ticket revenue by operator;
- a cost model which allows costs to be varied by operator and rolling stock type and which can be combined with estimates of revenue to generate forecasts of operator profitability; and
- an evaluation model, incorporating the model's various outputs - passenger demand, passenger distance, operator revenue, operator costs, profitability, user benefits (consumer surplus), overcrowding, and diversion to and from other modes.

Mode choice and assignment models

Fowkes et al (2004) explain that these models typically estimate changes to base demand using either aggregate multi-modal choice models or aggregate elasticity models based on generalised cost or generalised journey time. The forecast demand is then assigned to the network of services using a standard assignment routine which works on the basis of a hierarchy of optimal passenger strategies to transverse the network.

Two examples of this approach, used in the UK are:

- The National Rail Model (NRM) - Developed by Faber Maunsell on behalf of the Department for Transport, this is a strategic model covering all rail stations in Britain, as well as those on the London Underground. Fowkes et al (2004) explain that "the model works in an iterative way moving through a number of key sub-models, the most important being a mode choice model and a trip assignment model" (Fowkes et al, 2004). A multi-modal trip matrix is generated by the mode choice model, and this matrix is then passed to the EMME/2 assignment package which loads a passenger demand matrix to a network of rail services. The assignment is based on the concept of optimal strategies whereby passengers choose a set of paths through the network and board the first train to arrive at their destination; as opposed to an individual based choice mechanism
- The PLANET Suite of models - Also based on the EMME/2 network assignment package, this was originally commissioned by British Rail in the early 1990s and developed more recently by Jacobs and Atkins on behalf of the UK Strategic Rail Authority. Fowkes et al (2004) explain that "the model works by assigning a base demand matrix to the network, before estimating base

generalised journey time matrices which are passed to an elasticity model to estimate the demand impact of changes to the network" (Fowkes et al, 2004). The revised demand matrix is then fed back into the assignment model to be loaded onto the network to generate forecasts of passenger kilometres, total passenger hours, un-crowded passenger hours, crowded passenger hours, passenger boardings and train kilometres.

Summary

For rail, it would appear that there are no existing models that directly address the questions being analysed within DIFFERENT. One key difficulty is that most existing rail models are based on some sort of built-in response or elasticity on the part of end-users, but one issue for DIFFERENT is that we do not yet have sufficient evidence on responses to changes in infrastructure charges on the part of operators. More generally, existing models focus on the end-user market rather than the market for infrastructure services. As highlighted earlier, the perspective of rail models tends to be that of individuals that have to choose among alternatives. Costs, times, etc. are those incurred by end-users (I.E. passengers) rather than operators. The end-user market and the market for infrastructure services are, of course, linked, so it may be fruitful to have a model of infrastructure services somehow linked to a model of end-user demand so as to estimate the knock-on effects, or so as to allow for iteration between the demand for infrastructure services and the demand by end users. Such an exercise may, however, not be possible within DIFFERENT'S resources and we may need to take a more pragmatic approach. It may be possible to adapt one of the existing models of rail demand for use in modelling demand for infrastructure services. Alternatively, it may be possible to use one or more of the existing models (The National Rail Model, PRAISE or PDFH for example) to test scenarios and generate outputs to serve as input to discussions with industry stakeholders.

5.2.3 AIRPORTS

In the case of airports (and similarly for railways and even more so for ports), there are very few models addressing the issue of differentiation of tariffs. Most modelling efforts have been devoted to analyse demand behaviour, though there are also some models of interest that consider the case of congestion and environmental impacts. In what follows the following types of models are considered:

- Airport demand models;
- Airport congestion pricing models;
- Airport pricing models based on environmental damage and noise.

Airport demand models

Two main types of models can be used for airport demand (SH&E, 2003):

- Airport demand allocation models;
- Air service forecasting models.

Airport demand allocation models

These models try to explain the catchments area of several airports that are in competition, at least for some types of traffic. For instance, Ashford and Benchemam (1987) considered the air fare, flight frequency and access travel time as the most important explanatory variables. Other authors like Harvey (1988) include also some measure of ground access quality. The air fare variable seems to be very significant, particularly for non-business passengers. Other more recent studies in this respect are Pels et al. (2003) and Mandel (1999)

Air service forecasting models

These are typically aggregated models of demand forecasting in which future demand levels are explained by other variables as past demand levels, airport charges, or even macroeconomic indicators of the region where the airport is located, and so on.

The analysis of demand is closely related with the concept of elasticity that in turn is very relevant for the DIFFERENT purposes. It should be mentioned here, however, that direct estimates of airport price demand elasticities are very scarce.[28] On the contrary, estimates of price demand elasticities in the case of airlines services (i.e. final demand or airline services that relates passengers carried by airlines and air fares as paid by passengers) are abundant.[29]

Airport congestion pricing models

Airport congestion pricing models look for optimal congestion charges, taking into account the effects that different prices have on delay costs and traffic rates. Models of congested air transportation systems fall into three categories (Daniel and Pahwa, 2000):

- Standard peak-load pricing models
- Deterministic bottleneck models
- Stochastic bottleneck models

Detailed characteristics of each of these models are described below.

Standard peak-load pricing models

Peak-load pricing models determine equilibrium congestion fees from estimated demand and delay functions that vary by time of day (see, for example, Morrison, 1983, and Morrison and Winston, 1989). Demand functions give the hourly airport demand by each type of aircraft, with demand in each period being a function of its average full price (monetary price plus the value of delay time). These models have non-structural specifications of delay functions and ignore traffic adjustments in response to congestion fees.

By imposing a congestion fee equal to the cost of the difference in time between the marginal social delay and the private delay curves, the equilibrium moves to the intersection of the marginal social cost (delay) and marginal social benefit (demand). In this setup, equilibrium congestion fees for each hour are computed.

Deterministic bottleneck models

Deterministic bottleneck models include intertemporal traffic adjustment, but use simple queuing or delay processes (see, for example, Vickrey, 1969, and Arnott et al., 1993). Traffic rates and queue lengths are determined endogenously.

Originally designed to model highway congestion, the bottleneck model is also applicable to aircraft queuing during arrival and departure banks at an airport. To minimize connection and layover costs, hub-and-spoke networks schedule arrivals and departures at hub airports in banks of flights. Unlike standard peak-load pricing models, these models estimate efficiency gains from congestion pricing when traffic rates adjust intertemporally in response to the fees.

Stochastic bottleneck models

Pure queuing-theoretic models capture the effects of stochastic arrivals on the evolution of queues, but assume exogenous arrival rates and do not include intertemporal traffic adjustments. The stochastic bottleneck model, due to Daniel (1995, 2001), adds stochastic shocks to aircraft operating times and time-dependent stochastic queuing theory to deterministic bottleneck models. In summary,

[28] See for instance Kanafani and Gobrial (1985)
[29] See for instance Oum et al. (1992) for a survey on this.

the stochastic bottleneck model includes stochastic queues, time-varying traffic rates, and endogenous, intertemporal adjustment of traffic in response to queuing delay and fees.

One of the main differences between deterministic and bottleneck models relates to the fact that the stochastic model produces smooth and continuous variation in traffic rates because of the non-linear relationship between traffic rates and expected queue length. However, in deterministic bottleneck models, traffic rates are step functions over time.

The stochastic model determines equilibrium traffic patterns, queuing delays, lay-over costs, congestion fees, airport revenues, efficiency gains, and distributional effects of congestion pricing.

Daniel and Pahwa (2000) compare the three empirical models of airport congestion pricing explained above. They conclude that the models produce similar traffic patterns under weight-based pricing, but differ significantly under congestion pricing. Moreover, they demonstrate the importance of structural modelling of endogenous, stochastic traffic rates and queues that produce lower fees at peak and slack-demand periods than other models. They also show the advantage of tolls that vary continuously- instead of by hour- to spread the peak and moderate extreme fee levels. By demonstrating that such a charge involves modest changes in average fee levels and retains periods of low priced airport access, Daniel and Pahwa try to make this pricing mechanism more acceptable by policy makers, the industry and the public.

Airport pricing models based on environmental damage and noise

Airport charges may differ depending on the environmental damage and noise that airlines' operations impose to the society. However, there are few articles in the literature forecasting the effects that such differentiated charges will have on the demand and the social welfare of the overall economy.

Most of the studies use the hedonic price method to estimate the social cost derived from aircrafts noise and environmental pollution in the vicinity of the airport. This method is based on the household equilibrium marginal willingness to pay, which is used to extract the implicit prices of certain characteristics which determine property values, such as location, attributes of the neighbourhood and community, as well as environmental quality.

The environmental charge level is optimal if the rate is determined at a level where the marginal social cost of the externalities equals the marginal abatement cost of airlines.

Once the optimal environmental charge has been computed, the implications of such a charge on airline costs can be easily obtained. With an appropriate estimation of the demand elasticity and taking into account the market characteristics in which airlines are operating, the effects of different environmental charges on passengers demand can be also estimated.

5.2.4 MARITIME TRANSPORT

The text below relates to models and methods that are most commonly used to assess the relative attractiveness and competitiveness of seaports, some of which are related to price elasticities. However, there do not appear to be models that have been used specifically to predict effects of differentiated charges in ports.

Multicriteria analysis

An accepted rationale of port selection by shipping lines relates to the combined importance of quality of infrastructures, costs, service and geographical location. Multicriteria analysis enables port preference to be assessed based on the relative importance given to specific port selection criteria (Song and Yeo, 2004; Guy and Urli, 2006). Multicriteria analysis starts with the definition of a problem or a choice to be made, and the identification of possible alternatives. The results then help to influence and guide decision makers towards the criteria that need to be taken into account and their relative importance. With this information, different mathematical models can be used to produce an overall ranking of the alternatives considered.

Analytic Hierarchy Process (AHP) is a multi criteria decision making approach that employs pairwise comparisons to arrive at a scale of preferences among a set of alternatives. In AHP, a decision problem is decomposed into a hierarchy. In the context of ports, decomposing a choice ‘problem’ involves the structuring of a hierarchy in terms of the decision to select a given port, based on selection criteria, and decision alternative (i.e. other ports). Primary data can then be collected (e.g. through questionnaires) based on selected criteria for a given sample of ports. Using AHP methodology in a decision problem involves four steps (Zahedi, 1986):

1. Structuring the decision hierarchy (i.e. criteria, decision alternatives);
2. Collecting input data, depicted by matrices of pairwise comparisons, of decision elements;
3. Using the eigenvalue method to estimate relative weights of decision elements;
4. Aggregating relative weights of decision elements to arrive at ratings for decision alternatives.

In work by Lirn et al (2004), employing AHP methodology, the focus was on capturing the significance of subjective judgements affecting port selection. While supporting the role of qualitative factors in port selection, they argued that monetary costs remained the most significant factor in deciding a port’s attractiveness. Port attractiveness has also been assessed using Likert-style questionnaires to solicit the opinions of shipping lines that are major port users (Ng, 2006). Results have tended to suggest that port choice reflects a mixture of different factors, and that monetary and time factors on their own were insufficient to decide port attractiveness.

Optimisation techniques

Optimisation techniques is another method whereby factors such as the optimal location of ports and the consequent configuration of shipping service networks may be evaluated (Horner & O’Kelly, 2001; Baird, 2002). Use of multicriteria analysis was initially developed in reaction to perceived shortcomings of classic optimisation. Decision makers can rarely select a course of action on the basis of a single factor. Thus, decision making involves many criteria being taken into account and their relative importance. Nevertheless, optimisation remains central in transportation studies in general and particularly in research on shipping service networks (especially container shipping).

In their study, Veldman and Buckmann (2003) analysed the routing of West European container flows from the perspective of expansion of container terminal capacity at the port of Rotterdam. Logit models were tested to explain the market shares of traffic zones in the continental and overseas hinterland of the port of Rotterdam. Veldman et al (2005) extended this work by considering draft limitations at various hub ports as an explanatory variable in determining market shares as part of a range of quality of service and cost aspects. Based on data for 2001 and 1997, the quality of service variable was split into components such as Mohring effect variable, expressing quality of service aspects related to service frequency; a maritime access cost variable, expressing the additional costs of including a port in a shipping route; and a maritime resistance variable, expressing the time ships have to wait for the tide.

Port simulation models

Simulation models have been used extensively in the planning and analysis of ship-berth requirements. A variety of simulation models regarding port operations, coded in different simulation languages, have been developed by Gambardella et al (1998), Shabayek and Yeung (2002), and Demirci (2003). The impact of the arrival process of ships on the efficiency of the loading and unloading processes in port simulations was assessed by van Asperen et al (2003). Veenstra et al (2003) presented an economic evaluation of container terminals by operational simulations of generated cash flows.

Most container terminal systems are sufficiently complex to warrant simulation analysis to determine system performance. Simulation is recommended for analysing ship-berth link performance. Ship-berth link simulation models can be written by using general-purpose algorithmic languages and simulation languages (Schriber, 1991). Simulation modelling has been found to be a very effective method to examine the impact of introducing priority berthing for certain classes of ships. Simulation can also lead to a reduction in ship queues, and the average time a ship spends in a queue. However, as cost is a key measure in the selection of alternative strategies, ideally research needs to incorporate a cost analysis of the ship-berth link (Dragovic et al, 2005).

The ATENCO study undertaken on behalf of DG TREN (Analysis of the main Trans-European Network Ports' Cost Structures) sought to provide input for an EU strategy to achieve efficient pricing in ports (Haralambides et al, 2001). ATENCO used a questionnaire approach to gather information from ports and port users on pricing principles and strategies. The survey was complemented by a quantitative simulation exercise, which showed how different pricing schemes would affect traffic volumes in individual ports, with a focus on container traffic. Findings suggested that an across the board adherence to a specific pricing discipline may be expected to bring equality to the European port scene in the long run. However, short term implications would vary substantially.

5.2.5 STRATEGIC MULTIMODAL TRANSPORT (I.E. TRANSTOOLS, SCENES, ETC)

A relevant category of models consists of multimodal models used at strategic level for analysing mobility. In Europe there are several examples of such strategic models, using similar of dissimilar approaches. In the following, first a brief description of major examples of such models is provided, then considerations on the capability of such a type of models of dealing with tariff differentiation are being presented.

The TRANS-TOOLS model

TRANS-TOOLS is a research project co-funded by the European Commission under the 6th Framework Programme for Research and Development. The project aims to produce a European transport network model covering both passengers and freight, as well as intermodal transport, that overcomes the shortcomings of other existing European transport network models. The philosophy of the model is to build upon available models, taking the best features of each and linking these models in one software-based tool.

The TRANS-TOOLS model is made-up of different modules. These model components exchange information according to a sequential approach although feed-back effects are taken into account (e.g. transport costs and times produced by the assignment model are fed back to the modal split model).

The core parts of the model are, on the one side, the freight/logistics model based on the NEAC model and the SLAM model and, on the other side, the passenger model based on principles developed in the ASTRA and VACLAV models. Main inputs for these two models are the transport network, the socio-economic data and the transport level of service produced by the assignment model developed for TRANS-TOOLS. The model is refined by the inclusion of a spatial computable general equilibrium model, SCGE, based on the CGEurope principles, where transport costs/accessibility is a driving force for computing indirect effects (change in regional GDP) which are then fed in the freight and passenger models. The geographical coverage of the model is the enlarged EU plus accession countries and countries at the borders of the EU. The new member states and accession countries are modelled at the same zoning level as the EU-15, which is covered the NUTS-2 level, and NUTS-3 zones for the assignment phase for both the passenger and the freight models.

The TRANS-TOOLS model improves previous experience from several point of view. Major points concern a detailed treatment of intermodality and logistic chains, the inclusion of intercontinental flows (mainly for freight), the treatment of the feed back between infrastructure development end the economy, a methodology to include local traffic and address the effect of congestion on long distance traffic. For more information on the TRANS-TOOLS model see Burgess, A., et al. (2004).

The SCENES model

The SCENES model has been developed within several European projects. SCENES is a four-stage transport model, covering EU25 countries (plus Switzerland and Norway) with zones defined at the NUTS 2 level, while other European countries are more coarsely represented. The model simulates both passenger and freight transport and all relevant modes are considered: car, rail, air, ferry and coach for passengers; road, rail, maritime, inland navigation, air and pipeline for freight. Different road freight vehicles are considered according to their size. At the same time, both passenger and freight demand is segmented into a substantial number of homogeneous segments, with each of them facing transport supply characteristics that are appropriate to that segment.

Modal split is dealt with using a logit algorithm based on generalised cost. Monetary cost (as well as value of time) is defined separately for each demand segment, transport mode and, for some modes, also type of service (e.g. high speed rail vs conventional rail). Path choice is modelled by means of a stochastic user equilibrium (SUE) algorithm also based on generalised cost. Monetary costs per link are modelled (e.g. tolls for each vehicle type allowed on motorways). More details on SCENES can be found in ME&P et al. (2000).

The NEAC model

The NEAC model is a strategic freight model at the European level (not only EU countries but whole Europe: about 200 regions are in the database, most of which defined according to the NUTS 2 geographical classification). The model is built around the ‘transport chain’ concept, i.e.: the good is followed from the place of production via transhipment locations to the place of consumption where several modes can be used. The modes road, rail, inland waterways, sea and rest (pipeline, air) are available to for the transport chain. The transported products are coded into 11 commodity groups, at the so-called NSTR-1 digit level (or NSTR chapters, 10 in total) and a separate category for crude oil.
The model is conceived to simulate the observed transport flows and to forecast the future transport flows in terms of multimodal chains across regions. Therefore, a modal split module is included in NEAC where the modal-split is dependent upon a number of important factors. The module is based on a segmentation of the transport markets. Within each segment the development of the modal split is dependent on the transport time and the cost of transport of each mode in relation to other modes (cross elasticities). Such elasticities are different for each mode and according to commodity groups, distance and total tonnage on relations transported. For more elements on the NEAC model see NEA (1999).

The VACLAV model

The VACLAV model is a network-based Europe-wide forecasting model for passenger traffic. The model structure follows the classic four-step approach of trip generation, trip distribution, modal choice and trip assignment. The zonal system underlying the passenger transport demand modelling is NUTS 3. The geographical scope of the model is the European continent. Demand is segmented into two groups: business and non-business trips.

Within VACLAV, the modal choice set comprises four means of transport: passenger car, railway, air and coach and a logit model is used to perform modal split. Several elements describe the utility attached to each mode, e.g. costs, times, frequency, number of transfers. In-vehicle costs are defined separately from access/egress costs. For route choice, generalised users costs are calculated (derived from the utility functions in the mode choice model) for every link in the network and shortest path algorithms are applied. A detailed documentation of the VACLAV model is reported by Schoch (2004).

The Frisbee model

The Frisbee model was developed in a Finnish project in order to produce an information system for freight transport and logistics at the strategic level. Geographically, the system centres of the model is in North-eastern Europe and North-western Russia, but it also roughly covers other European countries and other continents. The freight transport system includes a description of the transport networks and terminals as well as the supply of transport services; unit costs at market price for modes of transport and type of goods, freight flows classified into 12 product categories and information about mitigating factors that affect transport flows.

The Frisbee model is used to analyse modal choice and route choice of freight flows in the study area. Therefore, a modal split and a path choice algorithm are implemented in the model. Costs are major determinants of travel behaviour simulated in the model denote and particularly the route choice of freight transport. Unit costs are defined in the model by product group, separately for the transport phase (Euro/ton-km) and the terminal phase (Euro/ton-km) and also varied by region. For more details see Lautso et al. (2005).

The TREMOVE model

TREMOVE is a policy assessment model to study the effects of different transport and environment policies on the emissions of the transport sector. TREMOVE models both passenger and freight transport in the EU15 plus 6 extra countries[30], and covers the period 1995-2020. The demand baseline is provided to TREMOVE by the SCENES model (see above).

TREMOVE consist of parallel country models, and one maritime model. Each country model consists of three inter-linked ‘core’ modules: a transport demand module, a vehicle turnover module and an emission and fuel consumption module[31]. The transport demand module describes transport flows and the users’ decision making process when it comes to making their modal choice. Starting from the baseline level of demand for passenger and freight transport per mode, the module describes how the implementation of a policy measure (or a package of measures) will affect the baseline allocation of demand across different modes and different vehicle categories. It is assumed that the transport users will select the volume of transport and their preferred mode based on the generalized cost for each alternative and applying Constant Elasticity of Substitution (CES) between alternatives. The generalized cost is the sum of money costs (including taxes and subsidies) and time costs.

On the passengers side, demand is segmented according to purpose (Commuting, Non-Working trips), geographical context (metropolitan, urban, non-urban), distance (short and long distance), time of the day (peak and off-peak time), mode (car, bus, motorcycle, slow, train/metro/tram, air), road vehicle size (large car, small car) and route type (motorway, other road). On the freight side, trip purposes are replaced by three commodity types: bulk, unitised and general cargo, alternative modes available are road, rail and inland navigation and road vehicle types are small and large trucks. The TREMOVE model does not include a network. Detailed information on the TREMOVE model can be found in De Ceuster et al. (2005).

Strategic multimodal models and fare differentiation

From the brief descriptions above, it can be seen that each strategic model has specific features and specialisations. In most of the cases, space is modelled in a relatively detailed way (with respect to the overall scale of the models) but the time dimension is ‘collapsed’ into an average day. In other cases (e.g. TREMOVE model), some more detail on the time side is counterbalanced by a coarser modelling of space (e.g. no network available).

Essentially, these models have been developed to analyse the transport sector at a large scale and to provide responses concerning the impact of elements like infrastructure development, demand growth, changes in relative competitiveness of modes, etc. Pricing is one of the measures that such models can handle, but under the consolidated assumption that fares can be different, within each mode, according to demand segments (e.g. business and non-business air fares or motorway tolls different for trucks and cars). Other sources of differentiation have not been commonly used or considered at the strategic level until a recent past, so models are generally not designed to deal with them.

A major aspect to take into account is that DIFFERENT concerns charges for operators (e.g. tariff to access to infrastructure for rail companies, costs of slots for airline companies, etc.), while all of these models consider the final end user of services. Therefore, operator tariffs differentiation can be dealt with only under the assumption that the whole difference of tariffs is passed on to the final users.

In the following tables, the capability of the models presented above to simulate fares differentiation is summarised for each of the main models. The sources of differentiation considered in the tables below are based on the analysis carried out in chapter 4.

[30] An ongoing project is aimed at extending the scope of the TREMOVE model, including a full coverage of EU25 and other European countries.

[31] A welfare cost module and a life cycle emissions module are also part of the TREMOVE model

Road							
Model	Source of differentiation						
	Road type	Destination	Time of the day	Day of the week	Period of the year	Vehicle type	Occupancy /load
TRANS-TOOLS	Yes	Partially(2)	No	No	No	Partially(4)	No
SCENES	Yes	Partially(2)	No	No	No	Partially(4)	No
NEAC	Yes	Partially(2)	No	No	No	No	No
VACLAV	Yes	Partially(2)	No	No	No	No	No
FRISBEE	Yes	Partially(2)	No	No	No	No	No
TREMOVE	Partially(1)	Partially(2)	Yes(3)	No	No	Partially(4)	No

Table 5.1: Capability of strategic models to simulate road charging differentiation

(1) TREMOVE distinguishes Urban, Motorway, Non motorway
(2) Different fares can be defined according e.g. to the region of destination, so distinguishing densely populated areas from rural areas or according the length of the trip (short distance, long distance), but e.g. fares increasing as city centre is approached cannot be defined.
(3) Peak time or off-peak time
(4) Two types of road freight vehicles are modelled in TREMOVE according to size, three types are modelled in SCENES still according to size. In TRANS-TOOLS, cars and trucks are modelled. Emission category is not distinguished in the models.

Rail(1)			
Model	Source of differentiation		
	Route	Slot time	Service type
TRANS-TOOLS	Yes	No	No
SCENES	Yes	No	Yes
NEAC	Yes	No	No
VACLAV	Yes	No	No
FRISBEE	Yes	No	No
TREMOVE	No	No	No

Table 5.2: Capability of strategic models to simulate road charging differentiation

(1) Tariffs for final users not for rail operators

Air(1)						
Model	Source of differentiation					
	Airport	Aircraft type	Slot time	Day of the week	Period of the year	Domestic or international
TRANS-TOOLS	Yes	No	No	No	No	Yes
SCENES	Yes	No	No	No	No	Yes
NEAC	No	No	No	No	No	No
VACLAV	Yes	No	No	No	No	Yes
FRISBEE	No	No	No	No	No	No
TREMOVE	No	No	No	No	No	No

Table 5.3: Capability of strategic models to simulate air charging differentiation

(1) Tariffs for final users not for rail operators

Maritime(1)			
Model	Source of differentiation		
	Port	Vessel size	Handling requirements
TRANS-TOOLS	Yes	No	Yes
SCENES	Yes	No	Yes
NEAC	Yes	No	Yes
VACLAV	No	No	No
FRISBEE	Yes	No	Yes
TREMOVE	No	No	No

Table 5.4: Capability of strategic models to simulate maritime charging differentiation

(1) Tariffs for final users not for rail operators

5.3. CONCLUSION

The analysis above demonstrates that several modelling approaches are used to analyse transport activities in quantitative terms and to forecast impact of measures on either the demand or the supply side. A classification of main approaches can be summarised as follows:

- "Mainstream" transport models (four stages): modal split (Logit-type models) and assignment algorithms (deterministic/stochastic; static/dynamic); these are used in urban transport models as well as in wider models at the European scale. These models are the most relevant and apply to the simulation of all modes of transport even though road demand typically receives more attentions;
- microsimulation models, used in the analysis of road demand in urban contexts;
- economic models like e.g. elasticities of substitution models which consider transport demand as the result of the behaviour of consumers rather than travellers.;

From the DIFFERENT point of view, there are a number of limitations to these modelling approaches. The main issues to be mentioned are:

- Road transport is much more analysed than other modes.
- The point of view is generally that of individuals that have to choose among alternatives. Therefore, also non-road modes are generally modelled from this perspective: costs, times, etc. are those incurred by users. Decisions of service providers (e.g. railway or airline companies) are generally assumed exogenously and not modelled.
- Space is generally modelled in much more detail than time (e.g. route choice much more than departure time choice; peak hours or whole average days are modelled and not different periods of week or year) but it is more a matter of applications that of methodologies.
- Vehicle differentiation is generally not relevant for the typical models and vehicle fleet size and composition is assumed exogenously as the elements which affect it are outside the domain of transport models. Therefore, replacing the vehicle type as reaction to a charging policy are generally not addressed by models.
- Most of the models are focused on demand behaviour and derived from engineering and statistical analysis. Other specific contributions about tariff differentiation, especially for the air sector, come mainly from the economic analysis and therefore they are quantitative methodologies but not simulation models.

A more general issue which is worth mentioning is that even when, in principle, several given sources of differentiation can be dealt with using a model, building a model able to simulate all the charging schemes can become a very complex task. For instance, a correct simulation of different charges requires a careful segmentation of demand; so a large number of segments has to be defined and this can be very demanding both in computational terms and because of the data requirement. Therefore, actual applications of models are often used to test simple charging schemes rather than complex ones.

6. CONCLUSION

The state-of-the-art of the existing body of economic theory on charge differentiation, behavioural strategies of adaptation to differentiated charges, current charging structures, and modelling approaches for simulating the reaction (transport demand) to price differentiation suggests the following conclusions.

Economic theory provides a complex picture. On the one hand, an analytical stream of economic theory suggests the optimal framework (the normative approach) for transport charges differentiation. It is reached pursuing economic efficiency, a concept derived from welfare economics, according to which transport charges (prices) should equate with marginal social costs in order to obtain the maximal social welfare. This implies that the price of transport services should be provided up to the point where the benefit for the marginal unit is equated with the costs of providing that unit (the so-called first-best rule).

On the other hand, a complementary stream of analysis questions the practical application of the concept of marginal cost in transport, due to technological, institutional and political reasons, opening the way for deviations from the first-best pricing rules, i.e. towards second-best pricing approaches. This means a move from a normative approach (how transport charges should be in order to ensure welfare maximization) towards a positive approach (how transport charges actually are in order to take account of several constraints).

In terms of impacts on charge differentiations practice, it can be said that following the normative approach a highly degree of charge differentiation is required, i.e. the charges should vary taking account simultaneously of several dimensions (variability of vehicle technology, time of travel, place of driving, driving style, etc). Conversely, a less differentiated structure of charges, reducing its intrinsic complexity, can be suggested following a positive approach.

The adoption of a less differentiated charge structure also emerges from the **behavioural theory**, according to which there are cognitive limitations that restrict the degree of complexity that people can deal with and thus the degree of differentiation possible. However, the behavioural theory also stresses the importance of motivational factors in accepting differentiated charges. Thus even if transport users are able to understand a complex pricing system and to predict prices in advance, it does not mean that they are willing to deal with these charges and to adjust their behaviour without a certain degree of acceptability.

The contributions provided by the behavioural theory approach assume that there is one point where more differentiation of charges does not lead to more users' adaptation, because people do not understand the system anymore. Thus, when looking at user's reaction of differentiated pricing, it seems reasonable to consider the question of people's acceptability together with their ability to respond to the price signals.

Current practice of the application of charges and, moreover, any differentiation within them is still very uneven within Europe as well as between and inside each transport mode.

Road (motorways and urban roads) and rail infrastructure show on average the highest degrees of differentiation and convergence, while airport and, even more so, maritime infrastructure lag behind. However, the likely future developments are positive. Promising technological developments, e.g. satellite communication devices, the start-up of the European satellite communication system GALILEO, extensive production of GPS and in-vehicle devices, etc, are deemed to favour the degree of charging differentiation with reference in general to all transport modes and road in particular. The effective realization of that will depend on the complementary convergence in the appropriate institutional and political sides.

The capability of the current **transport models** to simulate the impacts of charges differentiation on transport demand and supply depends on their specific features and field of specialization, e.g. the mainstream transport models: modal split (logit-type models) and assignment algorithms (deterministic/stochastic; static/dynamic) are used in urban transport contexts, strategic multimodal models are used for policies assessment affecting multimodal modes, etc. Concerning the impact assessment of charge differentiation, an important issue to be considered is that generally the modelled impacts of charge differentiation concern only the final users (transport demand) and not the strategies of transport operators, who pass all the charge variation on to the final consumers. In addition, the impacts arising from charge differentiation suffer from a series of limitations, like the prevalence of impact analysis involving road transport and its various dimensions.

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APPENDIX 1

CHARGING STRUCTURES FOR MOTORWAYS

APPENDIX 1: CHARGING STRUCTURES FOR MOTORWAYS

Forerunners (distance-based systems)

Country		Basic system	Vehicle scope	Geographic scope	Differentiation	Mark-ups	Regulatory charges	Use of revenues	Technology	Sources and general comments
Austria	*Existing*	Toll	>3,5 t (time based vignette for vehicles <3,5 t)	Motorways & some express roads	General: vehicle class (axles) Additional: Type of road (Sondermat strecken in mountainous areas), Time (Brenner motorway day/night)	Sondermaut strecken as a similar concept)	–	Motorways (Asfinag)	DSRC	http://www.asfinag.at/ http://www.asecap.com/english/mem-austria-en.html http://www.gomaut.at/go/default.asp
	Planned	–	–	Discussion on inclusion of parallel roads on hold indefinitely	–	–	–	–	–	No immediate plane
	Additional opportunities	None	All vehicles	All roads	Emissions class	Brenner (Sondrmaut strecken may already correspond to the maximum)	In urban and mountainous areas	Other transport or not transport use	–	–
Germany	*Existing*	Toll	>12 t	Motorways	vehicle class (axles), Emissions (Euro class)	–	–	Transport sector (road, rail, inland shipping)	GPS/GSM	http://www.bmvbs.de/Verkehr/strasse-,1436/lkw-maut.htm http://www.tollcollect.de
	Planned	–	–	Discussion on inclusion of certain parallel roads	–	–	–	–	–	No plans beyond inclusion of some parallel roads
	Additional opportunities	None	All vehicles	All roads	Emissions class	Hardly applicable (possible in lower Inn valley on Brenner link)	In urban (and mountainous areas) with congestion or environmental problems	Other transport or not transport use	–	–

Source: “A Price Worth Paying”, European Federation for TRANSPORT and ENVIRONMENT”

Traditional motorway operators (distance/matrix-based systems) 1/2

Country		Basic system	Vehicle scope	Geographic scope	Differentiation	Mark-ups	Regulatory charges	Use of revenues	Technology	Sources and general comments
France										
	Existing	Toll	All vehicles	Part of motorways network (approx. 8000 km; no tolls on e.g. urban motorways, some inter-urban motorways)	vehicle class (axles)	–	–	Motorways operator	DSRC	http://www.autoroutes.fr http.asecap.com.english/mem-france-en.html
	Planned	–	–	Additional links (e.g. Alsace?)	–	–	–	–	–	No Know plans
	Additional opportunities	–	–	All motorways, all roads	Emissions class	Lyon-Turin; Pyrenees	In urban and mountainous areas	Other transport or not transport use	–	–
Greece	*Existing*	Toll	All vehicles	<1000 km motorways	vehicle class (axles)	–	–	Motorways operators	DSRC	http://www.teo.org.gr http://www.asecap.com.english/mem-greece-en.html
	Planned	–	–	? (possibly additional / new motorways)	–	–	–	–	–	No Know plans
	Additional opportunities	–	–	All motorways, all roads	Emissions class	Possibly to Bulgarian border	In urban and mountainous areas	Other transport or not transport use	–	–

Source: “A Price Worth Paying”, European Federation for TRANSPORT and ENVIRONMENT”

Traditional motorway operators (distance/matrix-based systems) 2/2

Country		Basic system	Vehicle scope	Geographic scope	Differentiation	Mark-ups	Regulatory charges	Use of revenues	Technology	Sources and general comments
Italy	*Existing*	Toll	All vehicles	Part of motorways network (5600 km)	vehicle class (axles)	–	–	Motorways operators	DSRC	http://www.aiscat.it http://www.asecap.com.english/mem-italy-en.html
	Planned	–	–	–	–	–	–	–	–	No Know plans
	Additional opportunities	–	–	All motorways, all roads	Emissions class	Brenner link, Fréjus/Mont Blanc	In urban and mountainous areas	Other transport or not transport use	–	–
Portugal	*Existing*	Toll	All vehicles	Part of motorways network (1300 km)	vehicle class (axles)	–	–	Motorways operators	DSRC	http://www.brisa.pt http://www.asecap.com/english/mem-portugal-en.html
	Planned	–	–	–	–	–	–	–	–	No Know plans
	Additional opportunities	–	–	All motorways, all roads	Emissions class	Not applicable	In urban areas	Other transport or not transport use	–	–
Spain	*Existing*	Toll	All vehicles	Part of motorways network (2800 km)	vehicle class (axles)	–	–	Motorways operators	DSRC	http://www.aseta.es http://www.asecap.com.english/mem-spain-en.html
	Planned	–	–	? (possibly additional / new motorways)	–	–	–	–	–	No Know plans
	Additional opportunities	–	–	All motorways, all roads	Emissions class	Pyrenean links	In urban and mountainous areas	Other transport or not transport use	–	–

Source: “A Price Worth Paying”, European Federation for TRANSPORT and ENVIRONMENT”

Traditional Eurovignette countries (time-based systems) 1/2

Country		Basic system	Vehicle scope	Geographic scope	Differentiation	Mark-ups	Regulatory charges	Use of revenues	Technology	Sources and general comments
Belgium	*Existing*	Eurovignette: user charge	>12 t	Motorways	EURO 0 - EURO IV+, 3/4 axles	–	–	Regions for transport projects	Manual/Sticker	–
	Planned	Flat-rat (time-based) all-vehicle vignette	Eurovignette + "e-vignette" for vehicles under 12 t	Motorways/all roads	Weight/axles	–	–	Under discussion between regions.	Electronic fee collection using number plate recognition	Plans for e-vignette for vehicles under 12t-scheduled for January 2008.
	Additional opportunities	Distance-based charges	>3,5 t/all vehicles	All roads	vehicle class (weight/axles); emissions	Not applicable	In urban areas	Other transport or not transport use	–	–
Denmark	*Existing*	User charge	>12 t	Motorways	EURO 0 - EURO IV+, 3/4 axles	–	–	–	Manual/Sticker	–
	Planned	No plans	–	–	–	–	–	–	–	No Know plans
	Additional opportunities	Distance-based charges	>3,5 t/all vehicles	All roads	–	Not applicable	In urban areas	–	–	–
Luxembourg	*Existing*	User charge	>12 t	Motorways	EURO 0 - EURO IV+, 3/4 axles	–	–	–	Manual/Sticker	http://www.do.etar.lu/vehaut/eurovignette.htm
	Planned	–	–	–	–	–	–	–	–	No Know plans
	Additional opportunities	Distance-based charges	>3,5 t/all vehicles	All roads	–	Not applicable	In urban areas	Other transport or not transport use	–	–

Source: “A Price Worth Paying”, European Federation for TRANSPORT and ENVIRONMENT”

Traditional Eurovignettes countries (time-based systems) 2/2

Netherlands	*Existing*	User charge	>12 t	Motorways	EURO 0 - EURO IV+, 3/4 axles	–	–	Motorways operators	Manual/Sticker	–

	Planned	Distance-based charges	–	–	–	–	–	–	–	Plans under discussion for possible introduction 2008
	Additional opportunities	Distance-based charges	>3,5 t/all vehicles	All roads	–	Not applicable	In urban areas	Other transport or not transport use	–	–
Sweden	*Existing*	User charge	>12 t	Motorways	EURO 0 - EURO IV+, 3/4 axles	–	(Stockholm congestion charge for all vehicles)	–	Manual/Sticker	–
	Planned	Distance-based charges	> 7,5 t under discussion	Motorways & major roads, possible regional exceptions	EURO class, Environmental characteristics	–	–	–	–	Plans under discussion not yet finalised
	Additional opportunities	–	>3,5 t/all vehicles	All roads	–	Not applicable	In urban areas	–	–	–

Source: “A Price Worth Paying”, European Federation for TRANSPORT and ENVIRONMENT”

Late starters (no system yet)

Country		Basic system	Vehicle scope	Geographic scope	Differentiation	Mark-ups	Regulatory charges	Use of revenues	Technology	Sources and general comments
Finland	*Existing*	None	–	–	–	–	–	–	–	–

		Basic system	Vehicle scope	Geographic scope	Differentiation	Mark-ups	Regulatory charges	Use of revenues	Technology	Sources and general comments
	Planned	None	–	–	–	–	–	–	–	Feasibility study but no plans
	Additional opportunities	Distance-based charges	>3,5 t/all vehicles	All roads	Emission Class	Not applicable	In urban areas	Other transport or not transport use	–	–
Ireland	*Existing*	None (but 3 Tolled links)	(all vehicles)	(3 motorway links)	(Vehicle class)	–	–	–	–	http://tinyurl.com/qq4re
	Planned	Toll (PPP for road construction)	All vehicles	New roads/motorways	–	–	–	PPP	–	Provision for public consultation on tolling proposals.
	Additional opportunities	Toll	>3,5 t/all vehicles	All motorways/all roads	Emission Class	Not applicable	In urban areas	–	–	–
United Kingdom	*Existing*	None (but 42 km Tolled on M6)	(all vehicles)	(42 km motorway)	(Vehicle class)	–	(London congestion charge)	–	–	http://www.m6toll.co.uk/
	Planned	Toll (Lorry Road user charges, LRUC)	> 3,5 t	All roads	Vehicle class	–	(Several cities plan congestion charges)	Treasury (comp. for red. excise duty)	ETC	Plans postponed
	Additional opportunities	None if plans realised	All vehicles	None	Emission Class	Not applicable	In urban areas	Other transport or not transport use	–	–

Source: “A Price Worth Paying”, European Federation for TRANSPORT and ENVIRONMENT”

New Member States (various situations) 1/2

Country		Basic system	Vehicle scope	Geographic scope	Differentiation	Mark-ups	Regulatory charges	Use of revenues	Technology	Sources and general comments
Czech Republic	*Existing*	User charge	All vehicles, 4+ wheels	Motorways and express-ways (740 km)	Weight	–	–	Regions for transport projects	Manual/Sticker	http://wwwmdcr.cz/en/

	Planned	Toll for heavy goods vehicles	First> 12 t later >3,5t	Motorways and express-ways (2000 km)	Axles, emission class (EURO 0-EURO III+), Day/night	–	–	Under discussion between regions.	Electronic fee collection, DSRC	Scheduled date of entry into force: 1st Jan 2007
	Additional opportunities	Toll	All vehicles	All roads	Emission class: EURO 0-EURO IV+	Limited applicability	In urban and/or polluted areas	Other transport or not transport use	GPS	–
Estonia	*Existing*	–	–	–	–	–	–	–	–	–
	Planned	–	–	–	–	–	–	–	–	No Know plans
	Additional opportunities	Toll	>3,5 t/all vehicles	All roads	Emission class	Not applicable	In urban areas	Other transport or not transport use	–	–
Hungary	*Existing*	User charge	All vehicles	Approx. 70% of motorway network(670 km steadily increasing)	Weight?	–	–	Motorways	Manual/Sticker	http://www.aka.hu/ http://asecap.com/english/mem-hungary-en.html http://www.autopalya.hu/engine.aspx
	Planned	Toll	> 3,5 t	motorways, expressways	Weight	–	–	Motorways	Electronic toll collection, DSRC	Scheduled date of entry into force: 1st Jan 2007
	Additional opportunities	None if plans implemented	None	All roads	Emission class	Not applicable	In urban areas	Other transport or not transport use	GPS	–
Latvia	*Existing*	–	–	–	–	–	–	–	–	–
	Planned	–	–	–	–	–	–	–	–	No Know plans
	Additional opportunities	Toll	>3,5 t/all vehicles	All roads	Emission class	Not applicable	In urban areas	Other transport or not transport use	–	–

Source: “A Price Worth Paying”, European Federation for TRANSPORT and ENVIRONMENT”

New Member States (various situations) 2/2

Lithuania	*Existing*	–	–	–	–	–	–	–	–	–
	Planned	–	–	–	–	–	–	–	–	No Know plans
	Additional opportunities	Toll	>3,5 t/all vehicles	All roads	Emission class	Not applicable	In urban areas	Other transport or not transport use	–	–
Poland	*Existing*	User charge	> 3,5 t (+ motorway toll for all motorised vehicles)	Motorways and national roads	Weight, Axles, Emissions (EURO 0-EURO II+)	–	–	–	–	http://www.gddkia.gov.pl/

	Planned	User charge	> 3,5 t	All national roads	Vehicles type, Weight, Emission class (EURO 0-EURO II+)	–	–	–	Not yet decided	Draft legislation not yet approved
	Additional opportunities	Toll	All vehicles	All roads	Emission class: EURO 0-EURO IV+	Possible applicability, High Tatras	In urban and/or polluted areas	Other transport or not transport use	GPS	–
Slovakia	*Existing*	User charge	All vehicles	Motorways and 1st class road	Weight	–	–	Motorways	Manual/Sticker	http://www.telecom.gov.sk/index.php
	Planned	Toll	>3,5 t initially; all vehicles from 2011	Motorways (340 km), expressways (80km) + later introduction of parallel trunk roads	Vehicles type, Weight, Emission class	–	–	Motorways	EFC; DSRC, switching to GPS from 2008-2012	Scheduled date of entry into force: late 2007
	Additional opportunities	None if plans implemented	All vehicles	All roads	Emission class: EURO 0-EURO IV+	Possible applicability, High Tatras	In urban and/or polluted areas and mountains	Other transport or not transport use	GPS	–
Slovenia	*Existing*	Toll	All vehicles	Motorways (440 km)	Vehicle height, Axles	–	–	Motorways	EFC/DSRC for cars (manual for HGVs)	http://www.dars.si/ http://www.asecap.com/english/mem-slovenia-en.html
	Planned	Toll	All vehicles	Motorways	Emission (environmental characteristics?)	–	–	Motorways	EFC for HGVs, technology as yet decided	Plans not yet finalised
	Additional opportunities	None	None	None	Emission class	Alpine links	In urban areas and mountains	Other transport or not transport use	GPS	–

Source: “A Price Worth Paying”, European Federation for TRANSPORT and ENVIRONMENT”

APPENDIX 2

LIST OF AIRPORTS ANALYSED

APPENDIX 2: LIST OF AIRPORTS ANALYSED

Country	Airport	Web	Other sources / Other information
Austria	Vienna	www.viennaairport.com	http://www.bmvit.gv.at/en/verkehr/aviation/index.html
Belgium	Brussels Intl	http://www.brusselsairport.be/	http://www.mobilit.fgov.be/fr/index.htm
Cyprus	Larnaca	Not available (Data obtained from GRACE)	http://www.mcw.gov.cy/
Czech Republic	Brno	http://www.airport-brno.cz/index.php?id=0&lang=en	http://www.mdcr.cz/en/Air+Transport/Air+Transport.htm Slots coordination system: http://www.slot-czech.cz/en/site/company/intro.htm
	Praga	http://www.prg.aero/en/site/klient/klient_index.htm	
Denmark	Aalborg	www.aal.dk	
	Copenhagen (Kastrup)	www.cph.dk	
Estonia	Tallin	http://www.tallinn-airport.ee/	Estonian Civil Aviation Administration: http://www.ecaa.ee/atp/?keel=en
Finland	Helsinki (Vantaa)	www.helsinki-vantaa.fi	http://www.finavia.fi/home
France	Nice	http://www.nice.aeroport.fr/include/default.asp?l=2	www.aviation-civile.gouv.fr www.aeroport.fr
	Paris / Charles de Gaulle	http://www.aeroportsdeparis.fr	
	Paris/Orly	http://www.aeroportsdeparis.fr	
	Marseille	http://www.marseille.aeroport.fr/eng/index.jsp	
	Lyon	http://www.bron-airport.com/	
Germany	Stuttgart	http://www.flughafen-stuttgart.de	ADV German Airport Association: www.adv-net.org
	Rostock-Laage	http://www.rostock-airport.de/	
	Berlin-Tempelhof	http://www.berlin-airport.de/	
	Berlin-Schönefeld	http://www.berlin-airport.de/	
	Berlin-Branden	http://www.berlin-airport.de/	
	Berlin-Tegel	http://www.berlin-airport.de/	
Greece	Athens International airport	http://www.aia.gr/	Hellenic Civil Aviation Authority: www.hcaa-eleng.gr
Hungary	Budapest - Ferihegy Airport	http://www.bud.hu/	
Ireland	Dublin	http://www.dublinairportauthority.com/index.html	
Italy	Rome, Ciampino	www.adr.it (Data obtained from GRACE)	http://www.infrastrutturetrasporti.it/page/standard/site.php http://www.assaeroporti.it/
	Rome, Fiumicino	www.adr.it (Data obtained from GRACE)	
Latvia	Riga	www.riga-airport.com (Data obtained from	

Country	Airport	Web	Other sources / Other information
		GRACE)	
	Liepaja	www.liepaja-airport.lv (Data obtained from GRACE)	
Lithuania	Vilnius	http://www.vilnius-airport.lt/index.php?lang=en	State Enterprise “Oro Navigacija”: www.ans.lt
Luxembourg	Luxembourg	www.lux-airport.lu	
Malta	Malta Intl.	www.maltairport.com (Data obtained from GRACE)	
Netherlands	Amsterdam Schipol	www.schiphol.nl (Data obtained from GRACE)	
Norway	Oslo	www.osl.no	http://www.avinor.no
Poland	Warsaw Frederic Chopin	www.chopin-airport.pl	
	Krakow-John Paul II Intl.	www.lotnisko-balice.pl	
	Katowice Intl airport	www.gtl.com.pl	
Portugal	Lisbon	www.ana-aeroportos.pt (Data obtained from GRACE)	
Slovakia	Bratislava airport	www.airportbratislava.sk	
Slovenia	Ljubljana	www.lju-airport.si	
Spain	All airports	www.aena.es	
Sweden	Stockholm Arlanda	www.arlanda.com (Data obtained from GRACE)	
Switzerland	Zürich	www.uniqueairport.com (Data obtained from GRACE)	
United Kingdom	London Heathrow	www.baa.com	
	Manchester Intl	www.manchesterairport.co.uk	
	Gatwick	www.baa.com	
	Scottish airports: Aberdeen, Glasgow and Edinburgh	www.baa.com	