Implementation of **M**arginal **C**ost Pricing in Transport –
Integrated **C**onceptual and **A**pplied **M**odel Analysis

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2 EXECUTIVE SUMMARY

The need for pricing reform in transportation has been a major topic in policy discussions for over a decade, starting from the early 90's in most countries. The view that marginal cost pricing should have a significant role in practical pricing systems has been gaining support, albeit slowly. In part this development has been implicit since the term marginal cost pricing is not always used, although clearly the idea has been to apply similar principles. An obvious trend in discussions on marginal cost pricing and pricing in transport more generally during the last few years has been the shift of focus from the derivation of optimal pricing rules to practical implementation problems. In particular, it has been recognised that marginal cost pricing cannot be universally implemented simultaneously across modes, regions, and any other relevant dimension (‘big bang’), for many reasons.

This observation immediately raises a number of questions, such as: Which modes or parts of the network should be addressed first? How far should we move towards full marginal cost pricing on each? What accompanying measures should we undertake? To what extent can the initial steps capture the benefits of full marginal social cost pricing? Are these first steps so good that later refinements or additional steps are relatively unimportant? Or are these steps so poor that they are hardly worth pursuing? And so on.

Very little work has previously been undertaken on these issues. Such work is however necessary to identify and understand possible barriers to implementation, to define optimal and feasible implementation paths, and to estimate the benefits that can be derived from the implementation. The aim of MC-ICAM has been to shed light on these and related questions. In this report we aim to draw out what we see as the key general policy and technical conclusions to emerge from the project.

MC-ICAM carried out theoretical and methodological analyses, studies on barriers and constraints, and modelling case studies. MC-ICAM has covered all main modes: urban transport, interurban road, rail, air and water. The presentation of our main conclusions is organised as follows:

- *Theoretical and methodological developments*
- *Key barriers and constraints*
- *Overall impacts of marginal cost pricing*
- *Key dimensions & key policy questions*
- *Phasing-in progress in the key dimensions*
- *Concluding comments*
- *Topics for future research*

Theoretical and methodological developments

MC-ICAM’s concern with a phased approach and implementation paths implied that a new territory was to be explored, both when looking at existing conceptual and empirical prior work. Indeed, empirical and theoretical analyses based on welfare economics have typically focused on the derivation of optimal transport prices from an ‘end-point perspective’. Almost no attention has been paid to the question how these prices should be implemented. Phasing in the implementation of marginal cost pricing is a subject that has attracted little (if any) previous research, theoretical or empirical. This is largely due to the comparative static approach typically adopted that does not (and cannot) address these kinds of questions. The key conclusions from theoretical/methodological considerations can be summarized as follows.

A key feature and contribution of MC-ICAM has been to make a conceptual distinction between barriers and constraints. The barriers represent factors or societal phenomena that cause the constraints. By constraints we refer to second-best constraints, which have attained growing attention in the recent economic literature. The barriers and their implied constraints appear in essentially different dimensions. Barriers are categorised according to distinct factors that may affect the implementation of marginal cost-based pricing. Constraints categorisation identifies different aspects of the pricing system itself: those aspects that the policymaker is not able or free to determine or choose in a fully optimal way. The conceptual distinction is thus clear and can be of obvious theoretical value. But MC-ICAM has aimed to argue that the distinction is not just a theoretical or analytic complication but has important practical value. A key feature is that a given barrier may give rise (contribute) to more than just one constraint, or conversely that different barriers may lead to similar constraints. For instance, one can easily think of examples of technological and practical barriers implying constraints on the coverage/scope, composition and degree of differentiation of the pricing measures. On the other hand, for instance flat tolling instead of perfect differentiation may equally result from a technological or practical barrier (technology does not allow differentiation), from an institutional barrier (a law prohibits charging a different toll to different groups) or from an acceptability barrier (people find it unfair that different groups would pay different tolls). However, much uncertainty remains about the exact nature of the barriers and constraints and the link between them.

MC-ICAM has defined implementation paths as a sequence of constrained second-best optima. Our aim has been to develop a conceptually satisfactory approach that is practically feasible to implement, given (a) the current theoretical level of understanding and (b) limitations of the models that were used in the modelling case studies. Once the second-best constraints are known the corresponding second-best optimum can be found – at least in theory. If we have a reason to suppose that the barriers will or can be eased over time, the implications of this for the constraints may then be considered and a new second-best optimum found. Thus we see the optimal implementation path as a sequence of second-best optima, each better than the last, that becomes feasible as the constraints are eased. Naturally, this approach has both theoretical and practical limitations, but we felt there was available no better alternative.

Key barriers and constraints

Drawing on these theoretical and methodological conclusions, MC-ICAM has proceeded to seek to identify key barriers and constraints for urban and interurban road transport, and for urban public transport, rail, air and sea. For this purpose we have drawn on three sources: literature (academic, earlier EU projects and policy documents), case studies of attempts at implementation, and interviews with individuals responsible for policy design and implementation. We have aimed to provide a comprehensive picture of the relevant barriers and constraints, rather than going into in-depth analysis in individual cases. This objective of research was motivated by the fact that many other research projects and demonstrations already have produced detailed local and country specific analyses of potentially important barriers and constraints and related issues. While these accounts have provided extremely valuable information, they alone cannot provide for a rigorous analysis of the existence and strength of barriers and constraints. More work on these issues is needed.

The main (key) barrier for urban and interurban road transport pricing is acceptability. Studies generally conclude that the benefits and costs of marginal-cost-based pricing of roads fall unevenly on the population, with the benefits widely and thinly distributed and the costs concentrated on a minority. Those who will gain often do not care due to relatively small per capita gains, whereas those who will lose will react strongly and join together to fight against the intended policy due to relatively intense welfare losses. This fundamental asymmetry between the benefits and costs is not very encouraging news for proponents of marginal-cost-based pricing in democratic societies, where policies are typically formulated as compromises, and where interest groups and lobbying matter. Indeed, acceptability barriers appear to be the reason why marginal cost pricing has not been implemented despite the substantial net benefits that economists and modellers' analyses have shown for long time. And these barriers pose the greatest obstacle to future implementation as well.

Acceptability is a smaller problem for rail, air and water modes. These modes are similar in the sense that they work through networks with stations or ports and generally a hub-and-spoke system. For rail, air and water especially important considerations relate to intermodal issues, competition issues, and estimates of marginal costs (scarcity is considered a particular problem).

Understanding how the barriers and constraints are linked, the nature and extent of uncertainty related to them, and the degree to which they can be eased over time is necessary for determining what government actions are the most appropriate and at which stage of the implementation path. This is crucial both for government actions that are aimed to phase in relevant pricing measures given the barriers/constraints and for actions aimed to affect the barriers/constraints themselves. A key problem here are the interdependencies ('vicious circle') between different types of barriers (technological, institutional and acceptability): in order to improve acceptability, technological and institutional problems should be solved first; on the other hand, their solving is difficult without having sufficient acceptability first.

Overall impacts of marginal cost pricing

The main conclusions from the MC-ICAM modelling case studies regarding overall impacts of marginal cost pricing can be summarized as follows:

(1) The main results:
- Small changes in volumes, and direct losses to a majority of users.
- Yet substantial overall welfare gains result.

(2) Resolution of the apparent paradox:
- Welfare gains derive not only from reductions in real transport costs but also indirect benefits from environmental improvements, reductions in levels of labour taxes and other distortions.
- Benefits accrue to non-users from the environmental and other improvements.

The impacts of full or first-best marginal cost pricing on total transport volumes and modal shares may often be rather minor as compared to the effects of other factors and trends in transport demand, technology, etc. The question naturally arises whether trying to introduce marginal cost pricing principles throughout the transport sector is worth all the effort required. Indeed, in many cases alternative policies and approaches may be more practical to consider. However, this does not deny the usefulness of considering marginal cost pricing principles (first-best, second-best) and corresponding modelling outcomes as theoretical benchmarks also in those cases.

In contrast, the computed welfare effects of marginal cost pricing (the theoretical difference between welfare levels at the first-best and the current situation) are typically rather significant. However, at the same time, the direct impacts to those who are the objects of pricing – the drivers/road users and consumers/households – are typically (there are exceptions!) negative: they will lose. The seeming contradiction with the fact above that the impacts on transport volumes are only marginal can be explained by that much of the benefits in both urban and interurban transport come from the assumed (optimal, efficient) use of the revenues to reduce distorting taxes (labour taxes in particular) elsewhere. Evidently these kinds of impacts do not directly influence transport volumes. Further major benefits derive from improvements in environmental quality.

As for the distribution of benefits of marginal cost pricing, as stated earlier, they will be widely distributed over the population, will be indirect and reaped only far in the future, and will be very small per capita; whereas most of the costs will fall on more or less homogeneous and easily identified groups and will be direct and immediate and relatively large per capita.

Still, significant direct and immediate benefits may arise in many individual cases, and moreover in a way that is acceptable to the public and politicians. Identification of such cases is crucial for the implementation. The MC-ICAM modelling case studies were able to identify many such cases. This fact has also been exemplified in a number of situations in practice (e.g. London, HGVs charging in Germany and elsewhere), both in urban and interurban transport, where transport pricing has either been introduced, is about to be introduced, or is under planning. It is however another matter how close these actual pricing schemes come to the true marginal cost pricing principles.

Key dimensions & key policy questions

In order to structure the whole range of potential questions that are likely to arise when considering implementation of marginal cost pricing, MC-ICAM identified so-called key dimensions of the pricing system. The five key dimensions and the corresponding key policy questions are:

1. Scope or coverage of the pricing system. Perhaps a natural first question regarding the non-technical (economic, social) aspects of the pricing system concerns its scope or coverage: What should be priced and who should pay? (The latter part of the question is equally relevant also in the next two categories "Level and composition of pricing measures" and "Degree of differentiation"). The answers in part depend on constraints regarding the number of market segments that can be priced distinctly e.g. by: geographical or spatial coverage, modal coverage, user groups covered and externalities covered. An important question related to these issues is about priority: in what order? This is affected by potential existence of synergy benefits.

2. Level and composition of pricing measures. A second set of key policy questions concerns the optimal prices themselves: What should be the level and composition (i.e. which pricing instruments to use) of prices? Here, allowance may need to be made for maximum tolls or price caps, budget constraints determining minimum or maximum total revenues etc, and also possible distortions in other links, modes, regions and sectors. Also these issues are affected by synergy benefits discussed above: synergy affects not only optimal order, but how much is priced.

3. Degree of differentiation. A third key question concerns the degree of differentiation – across vehicles / infrastructure users, over time and spatially. This in particular should be a key issue when considering pricing schemes in the longer run. The desired extent of differentiation depends on the additional welfare benefits associated with the further stages as compared to the costs of implementing a more sophisticated pricing system.

4. Use of revenues. It has long been argued by both researchers and policymakers that the use of revenues is a crucial issue for transport pricing. It has been argued, and also

shown in various studies, that the way revenues are used can have great welfare impacts – often much greater than the direct impacts of pricing. And it is demonstrated in many occasions to be a critical question from the acceptability viewpoint (public and political).

5. Supplementary measures and actions. It is similarly argued that the implementation of marginal cost pricing should be considered within broader policy packages including use of revenues and other supplementary non-price measures. Potential supplementary measures include investments to increase capacity, non-price regulation in various forms, and information provision systems. They may also refer to policies in related sectors like land use policies. Other types of policies that may be relevant to consider are related to institutional reform with the aim to remove or lower legal and institutional barriers. But similarly we can consider here also policies or actions that aim to directly promote technological development, and improve other practical preconditions or enablers such as estimates of relevant marginal costs and quality of relevant impact data.

The MC-ICAM modelling case studies investigated the impacts on social welfare and other relevant indicators of phasing-in of plausible pricing and other instruments in relation to these five key dimensions of the pricing system. The progress in these dimensions was interpreted as representing the progress along an implementation path.

Phasing-in process in the key dimensions

The MC-ICAM studies on barriers and constraints and the modelling case studies produced a great number of results and insights relevant for designing how the implementation should (or could) progress in the key dimensions of the pricing system. That is, results and insights directly relevant for designing an appropriate implementation path. Based on these and other similar results we can describe how the phasing-in of pricing measures most likely will or could (or in our view should) progress in the key dimensions. This means progress in relation to the scope of the system (how comprehensive?), in relation to the composition and level of prices (which instruments to introduce and at what levels?), in relation to the degree of differentiation (how far to go in this respect?). And so on. The key conclusions can be summarised as follows:

1. Sensible phasing and packaging of simple pricing measures with limited scope, relatively low charges and minimal differentiation can lead to substantial benefits already in early phases. Waiting for the ideal solution to be possible is no good excuse for not acting: the best strategy from the welfare viewpoint would be to start implementing with what is feasible now. But, we believe, this is the best strategy also from the acceptability viewpoint (as discussed next).

2. A careful choice for the initial steps of implementation is extremely important for building up acceptability for more comprehensive and sophisticated developments later on. This works both through demonstrating the benefits and increasing confidence. In general, the alternatives (strategies, policies, pricing measures/schemes) need to be looked at from both the efficiency/welfare and the acceptability perspective. At some points these contradict, at some other points support each other. It is especially crucial to identify the latter cases.

3. Scope of the pricing system. It is best to start with pricing measures or schemes that have a limited scope but which focus on areas and aspects/issues where problems are most acute. In road transport such simple schemes can be e.g. cordon tolls or km charge

for HGVs with limited scope and minimal degree of differentiation. One can move to the more comprehensive schemes only in the medium and long run as confidence and acceptability builds up. This also has been the way in which every successful implementation to date has proceeded.

4. Level of charges. Increases in charges need to be gradual; at the same time it is important/desirable that policies be time-consistent. It is often stressed that it is important that each new step improves overall social welfare and is not perceived as moving backwards. Second-best prices may imply great fluctuations, and regret type of issues may arise. A particular problem here from the viewpoint of implementation is to protect implementation paths from erosion that may occur when new elections take place during the execution of the path. But this of course is politics and this we have to accept. On the other hand, time inconsistency of policy may cause deliberate deviations from a planned implementation path even if there is no change (or even threat of change) of government.

5. Composition of charges. Appropriate packages of measures within and across modes are important for both efficiency (welfare) and acceptability. In an intermodal context this may mean e.g. environmental charges on all modes at once.

6. Degree of differentiation. The urban case studies showed considerable social benefits from differentiation of prices over time (peak and off-peak). The interurban case studies showed that geographic differentiation is likely to have remarkable social benefits and significant impacts on modal shares. But the studies also showed that differentiation is likely to benefit those (here road freight) who are the object of pricing.

7. Use of revenue is crucial. In most cases the use of revenue needs to be a central part of the policy package. The best use of revenue from the welfare perspective would be to reduce other distorting taxes, such as taxes on labour. However, the problem is that these tax reductions would be widely spread and would not be perceived as a benefit of the pricing reform. By contrast typically those who lose by specific pricing measures are a relatively small group that perceives its losses acutely and has the means and motivation to organise opposition. It may be necessary – in the beginning at least – to accept a less than optimal use of revenue in order to provide clear benefits to the losers and to buy off their opposition.

Because of the differences in starting points, problems, barriers and constraints it does not make sense to think of a single implementation path as being sensible for all situations. However, some general comments and suggestions can be made.

Urban:

In urban transport, where problems are acute and benefits of implementation clear, it is likely to be possible to move straight to higher prices and more complicated schemes than when this is not the case. This is in line with what is required for economic efficiency as well as acceptability. Thus we would expect to see the biggest most congested cities moving straight to fairly high charges and quickly to reasonably sophisticated schemes. Smaller cities with less acute problems may never progress beyond simple low cordon tolls. (The rather limited evidence we have (for instance (Jaensirisak et al 2002) suggests that acceptability will be enhanced by a conviction of the scale of the problems faced and of the improvements (especially environmental) that will be achieved, as well as by simplicity and low initial levels of charges.)

Interurban roads:
On inter urban roads, the major driver to reform comes from the wish of some countries (central countries with through traffic) without motorway tolls to achieve a level playing field in terms of competition for their road hauliers with those from countries where annual taxes and fuel taxes are low but where motorway tolls are in force. Many of the former countries are reluctant to impose motorway tolls themselves because of possible diversion to other roads, and thus need a more sophisticated system of charging heavy goods vehicles. If they do move to a GPS based system, the technology is then in place both for added sophistication of hgv charging (by time and place) and the extension of charging to all vehicles. Where the geography of the country involves large cities at relatively large distances (Spain, France) a continued reliance on motorway tolls may be more adequate.

Rail, air and water:
In the rail, air and water sectors, reform of infrastructure charges will be more heavily linked to intra and inter modal competition. In countries where there is little intra-modal competition and where the mode is strongly placed relative to other modes, the level of charges will be less important an issue than where inter and intra modal competition is strong. It is also likely that acute capacity problems will focus attention on pricing to reflect scarcity. The stronger competition and the more acute capacity problems the more sophisticated a system is likely to be both justified and acceptable.

All in all, it is fair to admit that it is hard to generalize too strongly on the basis of the case studies carried out. Exactly because an implementation path is interpreted as a sequence of second-best optima, defined by successive sets of constraints on pricing which in turn depend on successive sets of underlying barriers, and it is the latter element that will ultimately determine the viable implementation paths – and the most desirable among these – for a specific situation.

A final comment may be worthwhile on how our findings compare with progress in implementing EU policy on transport pricing. Within the EU, the principle of subsidiarity is deemed to apply to urban road pricing and to pricing the car in general. So these are matters for individual states. Given that the concentration has been on rail infrastructure and on charging for heavy goods vehicles (hgvs). The Directive covering rail infrastructure charges (2001/14) was needed largely for reasons of competitive policy with in the rail sector, but it represents an appropriate step on the implementation path in that it provides for marginal social cost-based pricing, with mark-ups where necessary for financial reasons (but they must not lose types of traffic, so there is an element of Ramsey pricing). Charging for scarcity is permitted, charging for environmental externalities is not required until this is implemented for competing modes. The revision of the Eurovignette proposed in 2003 may also be seen as a step on the implementation path. It provides for differentiation according to marginal social cost, but caps charges at average infrastructure plus uncovered accident cost and earmarks revenue for use in the transport sector. These measures were foreseen in the 1998 White Paper as requirements to promote acceptability, but they were expected only to remain in force for a short time. It is to be hoped that this is indeed the case and that implementation of a GPS based kilometre charge for hgvs may encourage comprehensive charging for all vehicle types. In the meantime, the next priority must be making progress with air and water transport.

3 OBJECTIVES OF THE PROJECT

Objectives of MC-ICAM

This MC-ICAM (Implementation of Marginal Cost Pricing in Transport – Integrated Conceptual and Applied Model Analysis) study is designed to address the following issues:

1. to develop the *phased approach to implementing marginal cost pricing;* and
2. to develop the practices for the *use of revenues in relation to marginal cost pricing.*

A general objective is to derive scientific or technical and practical policy conclusions related to these broad themes.

In a more detailed level, the key *technical achievements* of the study will be:

1. to define *optimal (full, first-best) end states* in the short, medium and long term compared to the current situations – for all important passenger and freight modes covering both urban and interurban issues, and taking account of relevant technological, institutional and national contexts;

2. to determine on the conceptual level the *necessary or optimal (second-best) implementation steps* – in terms of recommendations for actual pricing measures (policy packages) and for modal and geographical priorities, while taking account of the relevant technological and institutional constraints and policy contexts;

3. to present a *general framework for assessment* of marginal cost based pricing policies and the associated revenue use issues – allowing for the existing real-world models and the principles of cost-benefit analysis;

4. to carry out in-depth *modal level (urban, interurban road, rail, air, water) analyses* of the current pricing and other regulatory issues, and of the barriers to the marginal cost pricing in different modes;

5. to suggest the *transition path and the necessary or second-best optimal implementation steps* in different real-world policy-making contexts;

6. to conduct a thorough *empirical assessment of the welfare effects* – both efficiency gains and distributional impacts – related to the different steps identified towards the full optimum, as compared with the current non-optimal situations (with no marginal cost pricing); and

7. to give clear information to policy-makers on the *welfare gains* related to the optimal steps of the phased approach and to make *policy suggestions* for policy-making both at the strategic and more detailed levels: recommended strategy or taking the necessary steps towards efficient (and fair) pricing based on marginal costs.

Points 1, 2 and 3 are methodological, points 4, 5, 6 and 7 practical policy oriented.

4 METHODOLOGY

4.1 Introduction

Project MC-ICAM addresses issues related to the implementation of efficient or marginal cost-based pricing in transport. The term 'marginal cost-based' can be understood as referring to the fact that the prices may or need not be exactly equal to direct marginal costs but can be second-best prices, and that we are considering policy packages which typically, besides marginal cost prices, also contain other types of pricing instruments. For simplicity, we will in many places use the simpler term ‘marginal cost pricing’ to refer to the term ‘marginal cost-based pricing’. Sometimes the term ‘marginal social cost pricing’ is used, which also means the same thing (while highlighting the perspective of social optimisation). The relevant marginal costs are social marginal costs comprising of infrastructure costs, congestion costs, environmental costs and accident costs.

The need for pricing reform in transportation has been a major topic in policy discussions for over a decade, starting from the early 90's in most countries. The aims of the reform have broadly speaking been threefold: a more efficient use of the existing infrastructure; internalisation of environmental and other externalities (which as such is closely related to the first aim); and collection of revenue to facilitate funding problems. One key issue has concerned the role of marginal cost pricing in the reform. Could and/or should it be an essential (and a large-scale) part of a practically feasible solution, or should it be considered only as a (primarily theoretical) benchmark?

The view that marginal cost pricing should have a significant role in practical pricing systems has been gaining support, albeit slowly. In part this development has been implicit since the term marginal cost pricing is not always used, although clearly the idea has been to apply similar principles. An obvious trend in discussions on marginal cost pricing and pricing in transport more generally during the last few years has been the shift of focus from the derivation of optimal pricing rules to practical implementation problems. In particular, it has been recognised that marginal cost based efficiency pricing cannot be universally implemented simultaneously across modes, regions, and any other relevant dimension (‘big bang’), for many reasons. This has been recognised for instance by the 1998 White Paper on infrastructure charging (CEC, 1998) and the 2001 White Paper on the Common Transport Policy (CEC, 2001). Both documents spoke of gradual implementation with a number of stages and different rates of progress across modes.

This observation immediately raises a number of questions, such as: Which modes or parts of the network should be addressed first? How far should we move towards full or first-best marginal cost pricing on each? What accompanying measures should we undertake? To what extent can the initial steps capture the benefits of full marginal social cost pricing? Are these first steps so good that later refinements steps are relatively unimportant? Or are these steps so poor that they are hardly worth pursuing? And so on.

Very little work has previously been undertaken to identify and understand key barriers, to define optimal and feasible implementation paths, and to estimate the benefits that can be derived from their implementation. The aim of MC-ICAM has been to shed light on these and related questions. In this report, we aim to draw out what we see as the key general policy conclusions to emerge from the project.

MC-ICAM has covered all main modes: urban transport, interurban road, rail, air and water. It has produced direct policy conclusions as well as scientific/technical results that we hope can have indirect impact on policy in the longer term. This report summarises the main findings in both areas, with an emphasis on the policy conclusions. Much of the reporting of the empirical work in previous MC-ICAM reports has been organised by modes. Here the approach is cross modal, with the goal to present an integrated view. Also, rather than attempting to provide a comprehensive coverage we will highlight the issues that we regard as most important (perhaps, in some cases, also controversial). We will pay particular attention to the question of the value added of our work: what are the contributions compared to the state-of-the-art.

4.2 Key technical developments

MC-ICAM's concern with phased approach and implementation paths implied that new territory was to be explored, both when looking at existing conceptual and empirical prior work. Indeed, empirical and theoretical analyses based on welfare economics have typically focused on the derivation of optimal transport prices from an 'end-point perspective'. Almost no attention has been paid to the question how these prices should be implemented. Phasing in the implementation of marginal cost pricing is a subject that has attracted little (if any) previous research, theoretical or empirical. This is largely due to the comparative static approach typically adopted that does not (and cannot) address these kinds of questions.

The main results of MC-ICAM theoretical and methodological work on the implementation of marginal cost pricing in transport were in the following three broad areas:

- Developing the logic of a phased approach
- Examining second-best pricing
- Integrating theory, modelling and evaluation in the examination of alternative implementation paths

Sections 4.2.1-4.2.3 review the key concepts and results.

4.2.1 Phased approach

We next present, in subsections 4.2.1.1-4.2.1.3, our main ideas and conclusions concerning the phased approach under the following headings:

- Barriers and constraints
- Implementation path as sequence of second-best optima
- Templates for practical application

4.2.1.1 Barriers and constraints

Perhaps the most central concepts when defining and analysing implementation paths such as they have been defined in MC-ICAM are barriers and constraints. A key feature and contribution of the study has been to make a conceptual distinction between these two terms: while the constraints represent the concrete restrictions imposed on the pricing and other relevant measures, the barriers represent factors or societal phenomena that cause the constraints, they generate them. By constraints we refer to standard second-best constraints that have attained ample attention in the economic literature and were broadly reviewed in Rouwendal et al (2002). Barriers in turn are a much less investigated topic. And the causal relationships between the barriers and constraints are (to our knowledge) not addressed at all.

The relevant second-best constraints can be classified as limitations on the following aspects of the pricing system:

1. scope or coverage of the pricing system
2. level and composition of pricing measures
3. degree of differentiation of pricing measures
4. rules and principles governing revenue use
5. use of supplementary non-price measures

The term "scope or coverage of the pricing system" broadly speaking refers to, or answers the question "What will (or can) be priced?" This means limitations on the number of market segments that can be priced i.e. features such as: links or routes covered, geographical or spatial coverage, modal coverage, user groups covered, externalities covered, etc.

The term "level and composition of pricing measures" refers to the question "How will it be priced?" That is, it covers limitations on features such as: the types and combinations of charges and taxes used, maximum tolls or price caps, minimum or maximum total revenues, budget constraints, etc.

Specification of the "degree of differentiation" also answers the question "How will it be priced?" Here the focus is on the limitations on differentiation of prices over relevant sub-markets: in space (geographically, over links and nodes in networks), over time (peak/off-peak), and by person or vehicle characteristics.

The way the revenues generated will be used or allocated is a central question when designing marginal cost-based pricing policy packages and implementation paths. The revenues may be constrained or ear-marked to be used in the same mode, in another mode, in transport in general, in the same jurisdiction, to the disproportionate benefit of certain income groups, etc. Or alternatively the revenues can be circulated through the general state budget, with no explicit link to any specific uses.

The use of supplementary non-price measures refers to instruments such as investment, non-price regulation, information provision, etc. Also other policies (than transport) e.g. land use policies and institutional reform. Also production of better marginal cost estimates may be considered here.

Table 4.1 shows, in the left hand column, these five categories of constraints. The top shows alternative settings or perspectives of policymaking (and analysis). The individual cells show illustrative examples of actual constraints that may appear in different practical situations.

A key feature and contribution of MC-ICAM has been to make a conceptual distinction between barriers and constraints. As said above, the barriers represent factors or societal phenomena that cause the constraints, they generate them. MC-ICAM considered different ways of categorising the relevant barriers but one simple way is into the following three types:

1. technological and practical
2. legal and institutional
3. acceptability related

The barriers and their implied constraints appear in essentially different dimensions. Barriers categorisation considers different background factors or reasons that may hinder the implementation of marginal cost-based pricing. Constraints categorisation identifies different aspects of the pricing system itself: those aspects that the policymaker is not able or free to determine or choose in a fully optimal way. (For example, suppose tolling needs to be flat (=constraint) because there is no technology that would enable differentiation (=barrier).) The conceptual distinction is thus clear and can be of obvious theoretical value. But MC-ICAM has aimed to argue that the distinction is not just a theoretical or analytic complication (perhaps with some potential to illustrate the phenomena under study) but also has important practical value.

A key feature is that a given barrier may give rise (contribute) to more than just one constraint, or conversely that different barriers may lead to similar constraints. For instance, one can easily think of examples of technological and practical barriers implying constraints both on the scope or coverage, composition and degree of differentiation of the pricing measures. On the other hand, e.g. flat tolling instead of perfect differentiation may equally result from a technological or practical barrier (technology does not allow differentiation), from an institutional barrier (a law prohibits charging a different toll to different groups) or from an acceptability barrier (people find it unfair that different groups would pay different tolls). Table 4.2 illustrates the situation.

Table 4.1: Types of constraints on pricing for various settings with some examples of implied second-best pricing schemes

Type of constraint \ Setting/coverage	Unimodal	Multimodal	Multisectoral	Multi-regulator (horizontal and/or vertical)
Constraints on the number of market segments that can be priced, i.e. on the ability or freedom to charge optimal prices elsewhere	Not all links tolled Not all user groups tolled	Not all modes tolled Not all links tolled Not all user groups tolled	Existing non-optimal prices in other sectors (including labour markets for passenger transport; or polluting industrial sectors for freight transport)	Non-optimal (possibly zero) taxes by other regulators (vertically and horizontally) Tax competition and externality spill-overs
Constraints on the use of certain marginal cost based pricing measures (optimal price combinations), on their maximum levels and/or the minimum total revenues	Specific price caps Constraints on which externalities can be charged for	Specific price caps	Specific price caps	Specific price caps
Constraints on the degree of differentiation	Flat tolls (over time and space) Undifferentiated tolls over user groups	Undifferentiated tolls over modes Flat tolls (over time and space) Undifferentiated tolls over user groups	Non-differentiated congestion tolls for commuters and leisure trips i.e. not differentiated by trip purpose	Imposed equality of charges across jurisdictions
Constraints on the use of revenues	Required lowering of other taxes in that mode (for reasons of social acceptability) For example due to revenue neutrality in the case of kilometre based charge for roads	Required use of part of the revenues as subsidies in other modes (for reasons of social acceptability) or for environmental reasons: from road to rail	Impossibility to use the revenues to lower the most distortive taxes in the economy	Rules on the distribution of shares of total revenues over various governments (for reasons of institutional acceptability)
Constraints on the use of non-price supplementary measures	Fixed capacities Given network configurations Impossibility of setting local technology standards in combination with non-differentiated taxes	Fixed capacities Given network configurations	Impossibility of designing non-tax labour market policies	Impossibility of affecting locational choices of firms and households through spatial planning

Table 4.2: Barriers vs constraints

Implied second-best constraints on Underlying barriers	Scope or coverage of the pricing system	Composition and level of pricing	Degree of differentiation of pricing measures	Rules and principles governing revenue use	Use of supplementary non-price measures
Technological and practical barriers	X	X	X	X	X
Legal and institutional barriers	X	X	X	X	X
Acceptability related barriers	X	X	X	X	X

4.2.1.2 Implementation path as sequence of second-best optima

The existence of constraints on pricing and revenue allocation policies raises important issues for their optimal design. In a 'world without constraints', a welfare-maximizing government could freely choose values for the policy variables in order to realize the objective of welfare maximization. This is the world assumed in standard economic expositions of marginal cost pricing, and the resulting policy rules are often referred to as 'first-best policies'. When binding constraints exist, in contrast, we enter the world of second-best. The regulator's problem often becomes more complicated to solve when binding constraints exist. The challenge will be to set policy instruments such that welfare is maximized in such a way that the constraints applying are satisfied in the least distortive way possible. Such policy rules are referred to as 'second-best' policies.

MC-ICAM has taken the appropriate way of devising implementation paths as requiring identification of the barriers that prevent full implementation of marginal social cost pricing and the constraints (in terms of coverage, level or differentiation of prices or necessary accompanying measures including the use of revenues) to which they lead. Once these constraints are known, the second-best optimum in the light of those constraints can be found. If we have a reason to suppose that the barriers will or can be eased over time, the implications of this for the constraints may then be considered and the new second-best optimum found. Thus we see the optimal implementation path as a succession of second-best optima, each better than the last, that becomes feasible as these constraints are eased.

When barriers and constraints are the underlying reason why big-bang implementation of optimal pricing is not feasible, a natural definition of 'implementation paths' arises, and that could be formulated as follows: an implementation path is a sequence of second-best equilibria, along which constraints on policy instruments change over time, as the underlying barriers gradually erode or are removed in discrete steps over time. A phase in an implementation path can then be defined as the time period for which the set of constraints and their 'tightness' does not change, while a change would mark a phase transition.

It is clear that different types of implementation path are possible, for example as the nature of the initial constraints may differ across applications, and also because the order in which different (types of) constraints can be released may differ. Furthermore, the identification of the development of constraints over time does of course not yet define unique prices within each phase. For example, even if a constraint says that no differentiation of taxes is allowed in step 1, there are still an infinite number of tax levels that satisfy this constraint. Similarly, there are countless ways of selecting a certain sub-set of a limited number of links in a network to be tolled, and next an infinite number of price levels for each of these taxes. Finding the optimal way of respecting the constraints requires solution of a second-best problem, and this is the idealized procedure followed for determining an implementation path when its existence is motivated by the existence of barriers and constraints.

This approach was judged to be the best available, in particular when imposing the requirement that the approach should lend itself for practical application in large-scale network models. One major topic for future research that was identified, however, concerns the application of optimal control theory in the design of implementation paths. Because such optimal control problems often become hard to solve already when the dynamic problem contains two or more state variables, pursuing this path was judged inappropriate. There is just little hope that anything meaningful can be said for the multidimensional problems, characterizing the choice of an implementation path for multifaceted transport policy applications.

The foregoing has outlined the general principles used in MC-ICAM for the motivation, design and evaluation of implementation paths. Table 4.3 summarizes these insights for an imaginary implementation path that goes through 3 intermediate phases before the assumed optimal end state is achieved.

Table 4.3: Schematic representation of implementation paths in MC-ICAM

Initial conditions (Phase 0)	→	*Phase 1*	→	*Phase 2*	→	*Phase 3*	→	*End state (Phase 4)*
Barriers 0	→	Barriers 1	→	Barriers 2	→	Barriers 3	→	Barriers 4
↓		↓		↓		↓		↓
Constraints 0		Constraints 1		Constraints 2		Constraints 3		Constraints 4
↓		↓		↓		↓		↓
Initial policies 0		Second-best policies 1		Second-best policies 2		Second-best policies 3		Second-best or first-best policies 4
↓		↓		↓		↓		↓
Equilibrium 0		Equilibrium 1		Equilibrium 2		Equilibrium 3		Equilibrium 4
↓		↓		↓		↓		↓
Social welfare 0		Social welfare 1		Social welfare 2		Social welfare 3		Social welfare 4
(relative to BaU and first-best)		(relative to BaU and first-best)		(relative to BaU and first-best)		(relative to BaU and first-best)		(relative to BaU and first-best)

In each phase, a specific set of barriers exists, that creates specific constraints on the pricing and revenue use policies that can be implemented. Typically, the barriers and constraints will be removed over time. During each stage, the regulator seeks to perform optimal second-best policies that respect the exogenous constraints, implying a certain equilibrium with an associated social welfare level which can be interpreted by comparing it to the welfare that would apply in absence of the policy (BaU: Business as Usual) and the welfare that would apply under imaginary first-best policies during that phase.

An important aspect of the optimal design of an implementation path thus concerns the determination, for each phase, of the best among many possible policies that would satisfy the constraints applying during that phase. This may be hard to determine formally in practice, if anything due to the large dimensionality of transport network regulation. For the large network models used in MC-ICAM, this indeed turned out to be the case. Therefore, the implementation paths developed both for urban and inter-urban transport modelling purposes, while they certainly were based on the thoughts described here (and developed in the theoretical part of the project), however did not aim to find the true second-best equilibrium for intermediate phases during an implementation path.

When an implementation path is evaluated according to the approach sketched in Table 4.3, one not only obtains insight into the associated welfare effects per se, but the progress of social welfare – compared to BaU and optimal welfare – along the implementation path may also provide important insights into the question of which constraints are particularly harmful to social welfare. This would give an indication of the barriers that are the most attractive candidates for earlier removal, and hence might be an – admittedly ad hoc – first step into the direction of endogenising the time profile of barriers and resulting constraints.

4.2.1.3 Templates for practical consideration

Based on the theoretical approach and concepts discussed above, Niskanen et al (2003a) developed a simple tabular presentation of a model implementation path, summarising the dependencies and interactions of the various key dimensions and elements. This model, or template, is presented in table 4.4. The years representing short (0-3), medium (3-10) and long (10+) term are just indicative, as also of course is the division of the time path into four phases (also in Figure 4.3 above). These aspects can greatly vary between applications and situations.

Table 4.4, together with tables 4.1, 4.2 and 4.3 above, provide a simple blueprint that can be applied in practical cases.

Table 4.4: Model implementation path

Phases Key dimensions & second-best constraints	Phase 0 (current situation)	Phase 1 (short term, 0-3 years	Phase 2 (medium term, 3-10 years)	Phase 3 (long term, 10+ years)
Coverage or scope of the pricing system	Geographically or spatially (regions, network links, modes), types of externalities, user groups Observed constraints on coverage (the number of market segments that can be priced)	Improved coverage Implied second-best constraints on covering	Further improvement in coverage Implied second-best constraints fewer and/or less restrictive	Long term optimum in coverage Long term constraints on coverage
Composition (mix) and level of pricing measures	Pricing measures used Observed constraints on the mix of available pricing measures and their levels (price caps, budget or revenue constraint)	Improved mix of pricing measures used Implied second-best constraints on the mix and level of available pricing measures	Further improvement in the mix of pricing measures used Fewer implied second-best constraints and/or less restrictive	Long term optimal mix of pricing measures Long term constraints on the mix of available pricing measures and their levels
Degree of differentiation of pricing measures	Spatially, between user groups, in time, trip purpose, jurisdictions Observed constraints on differentiation	Improved differentiation Implied second-best constraints on differentiation	Further improvement in differentiation Implied second-best constraints fewer and/or less restrictive	Long term optimum in differentiation Long term constraints on differentiation
Rules and principles governing revenue use	Ways and mechanisms of revenue use Observed constraints on revenue use (allocation of revenues)	Improved revenue allocation mechanisms Implied second-best constraints on revenue use	Further improvement in revenue allocation mechanisms Implied second-best constraints fewer and/or less restrictive	Long term optimum in revenue use Long term constraints on revenue use
Use of supplementary non-price measures	Non-price measures used Observed constraints on use of non-price supplementary measures	Improved use of supplementary non-price measures Implied second-best constraints	Further improvement in use of supplementary non-price measures Implied second-best constraints fewer and/or less restrictive	Long term optimum in the use of supplementary non-price measures Long term constraints

4.2.2 Second-best vs first-best pricing

In this section we present, in subsections 4.2.2.1-4.2.2.3, our main thoughts and conclusions concerning second-best pricing vs first-best pricing under the following headings:

- Need for second-best pricing
- Pricing on links and nodes
- Pricing in transport networks

4.2.2.1 Need for second-best pricing

When considering the practical implementation of marginal cost pricing in transportation as well as other sectors, the economics literature and a number of earlier EU projects have emphasised the need to consider second-best policies. This is the case because of the likely existence of barriers and constraints within the transport sector or distortions elsewhere in the economy. Both these factors typically make straightforward and comprehensive implementation of marginal cost pricing undesirable.

Second-best pricing is an issue of paramount importance when considering implementation paths from a conceptual viewpoint – and, indeed, also when considering them from an empirical and practical viewpoint but with the desire to provide a solid motivation for the sheer existence and for the preferable design of implementation paths as an alternative for ‘big bang’ implementation of marginal cost based pricing. To see why, it is in the first place important to know that second-best pricing is defined as the most efficient type of pricing feasible when constraints on pricing render first-best pricing impossible. Secondly, although it is not at the analysts’ discretion to decide what the social objective of (transport) pricing should be, in our case one can infer this objective from the object of our study: marginal cost based pricing. This implies that the objective of the policy should be the maximization of social welfare, because otherwise there would be little motivation for pursuing marginal cost pricing in the first place. But when the maximization of social welfare is the objective, there is no fundamental reason why marginal cost pricing should *not* be implemented ‘as of day one’ – unless barriers exist that prevent such big-bang implementation from being feasible. Indeed, if such barriers do exist, and create constraints on the design of pricing measures, big-bang implementation becomes infeasible, and the question arises how pricing should be implemented. This summarizes MC-ICAM’s view on implementation paths: these are to be understood as a sequence of second-best (constrained) optima, jointly defined by the progress of barriers and the implied constraints over time, and the transport regulator’s (second-best optimal) response to this progress of barriers and constraints. For this reason, a thorough understanding of second-best pricing issues is an indispensable ingredient for the optimal design of implementation paths.

An important conclusion from many earlier projects on transport pricing is that policy packaging is important. This is especially true when considering second-best pricing: second-best policies almost by definition imply or require policy packaging. If first-best marginal social cost pricing were feasible, then we could examine that as a free-standing policy option in isolation from other policies. However, when dealing with the second-best we are inevitably led to seek packages in which the failure to achieve the ideal result with one policy instrument forces us to look at ways of improving the situation by the use of other policy instruments.

Rouwendal et al (2002) considered both first-best and second-best pricing policies and differences between them. Optimal pricing policies under first-best conditions only take into account the inevitable technological constraints under which the economic process takes place.

Under second-best conditions other constraints (such as the impossibility to introduce road pricing in the short run for political reasons) are present as well.

In general the presence of these additional constraints calls for departures from marginal-cost pricing in order to alleviate the welfare losses from the constraints. The size and the sign of the difference between optimal prices and marginal costs depend on the exact nature of the additional constraints and can vary from negligible to substantial. The additional restrictions that make the actual world different from the imaginary first-best world can originate from within the transport sector (such as the inability to introduce congestion tolling) but also from outside that sector. Distortions on the labour market, for instance, may be a reason for giving commuting traffic a special treatment. Moreover, the existence of different levels of policymaking may imply that policy variables are set so as to maximise the welfare of specific (e.g. regional) sub-populations and this may also influence the optimal values of policy instruments at different levels.

An important implication of the conclusions just listed is that it is impossible to make broad general recommendations statements (of the type: “prices should be equal to marginal costs”), except as a rough first approach. For useful policy assistance models are needed that incorporate the important details of the situation at hand to provide policy guidance in actual situations. This also makes it difficult to provide generally applicable guidelines for the implementation of marginal cost based pricing.

4.2.2.2 Pricing on links and nodes

Much of the literature on marginal cost pricing in transportation focuses on tolling links to reflect the costs of congestion. The main principles underlying link-based marginal cost pricing in an idealized first-best world are well understood, and MC-ICAM therefore focussed on specific second-best complications that become relevant when these idealized conditions do not prevail in reality. However, in some cases it may be more natural to consider tolling nodes. Even in road networks bottlenecks sometimes occur at the nodes. But for other transport modes, such as rail and air transport, congestion is often exclusively concentrated in the nodes. Links merging at the same node may have abundant capacity (throughout the day), but the node itself may not have enough capacity to deal with the traffic flows from all (relevant) links. And in a multimodal network there may occur bottlenecks on nodal points where travellers change mode.

To some extent, tolling links and tolling nodes is similar: an equal toll on all links leading to a particular node is equivalent to a toll on that node. Putting a price on the use of the node gives travellers an incentive to use other “paths”, not including the congested node. But tolling in nodes may also give rise to specific (second-best) complications.

The concentration of attention in the literature on tolling links in a network is of course related to the fact that automobile traffic is in many respects the dominant transport mode. In comparison with other modes, automobile traffic is rather special in that it leads to a large number of users of a network who act independently of each other (and are often assumed to be homogeneous). In other transport networks demand is often served by a limited number of companies, which are the users of the networks. In such situations strategic behaviour in which network users take into account the effects of their own behaviour on that of others cannot be ignored. For instance, the actions of large transport companies (rail companies, bus companies, airlines, shipping companies, freight companies etc.) can be of distinct influence on the profitability / welfare of (potential) competitors, nodal operators and final users (passengers). These companies may take these effects of their actions into account when deciding on their actual strategy.

The functioning of a transport market with a limited number of competitors may be quite different from that of a road network with atomistic users. As a consequence the regulator's task may also be much different in such circumstances. For instance, airport congestion can to some extent be expected to be 'internalised' partially by carriers that have market power, and in particular insofar as travel delays are caused for the airline's own (other) flights. The internalisation is more complete if the market share of the carrier is larger. As a consequence, there is only limited need to impose a congestion toll in these circumstances, and if a regulator should introduce such a toll, carriers with a low market share should pay a higher toll than those with a large market share. This already suggests that the insights obtained from analysis of road networks do not automatically carry over to other situations.

However, in a network where transport services are provided by a limited number of carriers who each have market power, prices cannot be expected to be equal to marginal costs. In such a situation, second-best optimal tolls must be expected to be influenced by the organisation of the industry. In other words: the fact that prices differ from marginal costs takes us to the world of second-best solutions and optimal second-best tolls should be expected to differ from the first-best tolls. The regulator faces two distortions: traditional transport externalities, such as congestion, and market power of the network operators. The optimal second-best toll in these circumstances may be lower than its first-best equivalent and can even be negative. The reason is that the operator's supply is lower than its first-best optimal value, and the second-best externality charge takes this into account and partly corrects for it.

Another aspect of such networks is that frequency of service becomes an important quality aspect. Automobile drivers may travel whenever they want, but trains and airplanes depart according to schedules that may imply substantial differences from desired departure times. If the frequency of service increases, such discrepancies decrease and this may further stimulate demand. The effect also works the other way around: profit maximising operators will offer a higher frequency of service if demand increases. This introduces an additional external effect into the model that was first studied by Mohring in the context of bus services.

The main policy conclusion is that specific second-best complications that may affect pricing at transport nodes often arise from the market power typically enjoyed by network operators using those nodes, which in itself result from scale and density advantages enjoyed by larger firms (a well-known example being the use of hub-and-spoke operations by major carriers). In such cases, the regulation of market power and that of externalities generated by operators' activities should ideally not be considered in isolation, but instead should be addressed simultaneously using analytical frameworks that can capture both distortions.

4.2.2.3 Pricing in transport networks

Independently of whether one considers link-based or node-based tolling, there may be various second-best complications that are relevant for the implementation of marginal cost based pricing in transport networks. Rouwendal et al (2002) discussed a number of these, focussing on the ones that have been identified in the relevant academic literature as being among the most important instances. We will briefly review some of these here.

Network issues: single mode

A classic example of second-best transport pricing concerns the – realistic – situation where not each and every link in a network can be priced. As a results, the second-best optimal tolls on the remaining links will reflect the spill-overs from these tolls, which may be negative (typically when the toll induces enhanced congestion on unpriced parallel links) or positive (typically when the toll reduces congestion on unpriced upstream or downstream serial links). As a result, the second-best optimal toll for a link may be below or above the equilibrium marginal external costs on that link. And an interesting, important second-best policy issue arises: apart from the challenge of finding the optimal second-best tolls for the priced links, the regulator faces the problem of choosing which links to toll. Recent research has provided some further insights in these matters, and have considered them both from a theoretical and a more practical viewpoint.

Paradoxically, the main general policy conclusion one can offer is that general conclusions cannot be offered. The efficiency of such second-best pricing schemes may literally vary between the impossibility of generating any welfare gains, up to examples where second-best pricing succeeds in achieving first-best welfare levels.

Other main conclusions are:

- Second-best prices are generally unequal to marginal external costs
- Quasi first-best prices, which naïvely ignore second-best complications and equate tolls to local marginal external costs, yield lower efficiency gains than first-best prices and may even reduce welfare compared to no-pricing
- Second-best tax rules can be very complicated, and the probability of the regulator making mistakes therefore increases likewise

Network issues: multiple modes

A related problem to the one just discussed arises when implementing pricing reform in one mode while a competing mode is non-optimally priced. Because competing modes are – in contrast to competing routes – often regarded as imperfect substitutes by the users, the second-best toll formulae may become even more complicated than in the case just discussed. This means that for any given model and its parameter values, optimal tolls (and capacities) can often be computed numerically, but that these optimal values cannot be characterized as an intuitive and reasonably general rule.

Heterogeneity

Unobserved heterogeneity among travellers does not necessarily imply that first-best (marginal cost) pricing is infeasible. As long as the heterogeneous travellers do not differ in their contribution to congestion (or other relevant external effects) and tolls are unrestricted, prices can still be made equal to marginal costs. However, if travellers differ in the external costs they impose on others, internalisation of these costs requires that they will also be treated differently. Sometimes this is impossible, and then the optimal second-best toll is often a weighted average of the optimal first-best tolls of the different groups. The change in social surplus associated with the second-best toll is usually much lower than that associated with the first-best differentiated toll.

The second condition under which heterogeneity among drivers cannot be ignored is when tolls cannot be varied continuously to reflect marginal social cost. If this is the case, optimal second-best tolls should in general take into account the heterogeneity of the travellers. For instance, in the bottleneck model the first-best optimum can be reached (assuming that drivers do not differ in the congestion cost they impose on others) when the toll can vary continuously over time. The first-best optimum may differ from the user equilibrium in the sequence in which the various groups pass the bottleneck. When the toll is restricted to, for instance, a limited number of steps, this may result in a situation that can be improved upon by differentiating the toll associated with each step on the basis of the heterogeneity of the drivers. An important aspect of such differentiation is that it allows the regulator to maintain the same sequence of groups in the second-best equilibrium as in the first-best equilibrium.

Differentiation of a toll on the basis of heterogeneity of drivers may be difficult to implement because the relevant differences are hard to observe or because of political difficulties associated with treating some groups differently from others. This implies that additional restrictions on the toll are imposed which prevent implementation of the optimal second-best toll.

Distortions in other sectors – notably the labour market

Imperfections in other sectors of the economy (existence of distortionary taxes on other markets, with special reference to the labour market; suboptimal income distribution; imperfect competition and market power, etc.) have consequences for second-best optimal pricing of transport services. The general conclusion from the existing literature on intersectoral issues is that they are almost always relevant for optimal pricing in the transport sector. Intersectoral issues matter because transport pricing interacts with other markets that may be strongly distorted. The most relevant relation is with the labour market, which is heavily distorted: labour taxes (income taxes, payroll taxes etc.) exist mainly because of the distributive concerns of the government but strongly distort the labour-leisure choice. This has two general implications. First, whenever there is an important pricing reform on a transport market, we have to take into account the effect on the labour market distortion. Second, since distributional goals can never be completely reached by using distortionary labour taxes alone (the marginal utility of income will not be equalised over income groups), the distributional concern will almost always be relevant in transport pricing.

Optimal tax and tax reform theory gives a number of important principles for transport tax design. We can identify at least six relevant results from the recent literature:

1. A separate tax treatment of journeys to work and other trip motives may be optimal and is well worth paying attention to.
2. Disregarding journeys to work, an optimal tax on transport will contain a Pigouvian term that is lower than the marginal external cost.
3. General equilibrium optimal tax theory is as much concerned with the optimal use of transport tax revenues as with the optimal level of transport taxes. The use of the revenues should be fully specified in applied models of transport taxation.
4. Similarly, a tax reform in the transport sector cannot be judged if we do not specify how we use the revenues.
5. The distribution of the costs and benefits has to be taken into account as long as the government pays attention to equity concerns.
6. There is no need to tax freight transport except to internalise the marginal external costs and to correct, in an indirect way, distortions in other sectors.

4.2.3 Integrating theory, modelling and evaluation

The MC-ICAM work aimed to contribute on one hand to the integration of (economic) theory and practical modelling, and on the other hand to the integration of modelling and evaluation. These issues were considered from the perspective of analysing implementation paths. An important contribution in the former respect was consideration of intermediate models, by which we refer to the kinds of simulation models that lie between conceptual or theoretical models and real life simulation models that describe specific transport networks in specific locations in practice. As for the latter task, we assessed previous model experiments with second-best pricing reforms; checked the capabilities of the model tools that were used for the case studies; and presented an assessment framework. We also considered suggested directions for further development of models and assessment practices. We next discuss, in subsections 4.2.3.1-4.2.3.3, these issues under the following headings:

- Intermediate simulation models for illustration
- Previous modelling exercises
- Modelling and assessment framework

4.2.3.1 Intermediate simulation models for illustration

Niskanen et al (2003a) considered intermediate models, which lie between theoretical (abstract) models and real life simulation models. The main purpose of such models is for illustration, to provide a link between theory and real world modelling, and to illustrate the application of the key theoretical concepts and ideas. These models have certain realistic features although they lack the complexity of the true real-world simulation models. The models focus on certain selected aspects of the implementation problem, but ignore some other aspects that would need to be allowed in a true policy analysis. Also, the implementation paths evaluated were hypothetical rather than representing any practical situation. The main point was that they should reflect the key theoretical principles and conceptual approach of the previous chapters.

We presented two such models. The first model is a simple network model, which focuses on the implications of network properties in contrast to simple analytic second-best models that typically restrict attention to pricing on individual or (at best) parallel links. The second model focuses on analysing distributional impacts of road pricing.

To illustrate the relevance of using such small simulation models, we briefly discuss the outcomes of the first among these. It considered, in the context of a very small network (3 links!) different implementation paths between the common initial state and the common first-best end-point. The paths looked as follows:

Example A	Example B	Example C	Example D
Base case			
Flat toll (equal across links)	Annual vehicle tax	Pay lane	Capacities
Congestion toll (differentiated across links)	Annual vehicle tax tax + cap	Pay lane + capacity pay lane	Cap + Flat tolls
First best			

The performance of these paths, in terms of welfare gains, is shown in Figure 4.1.

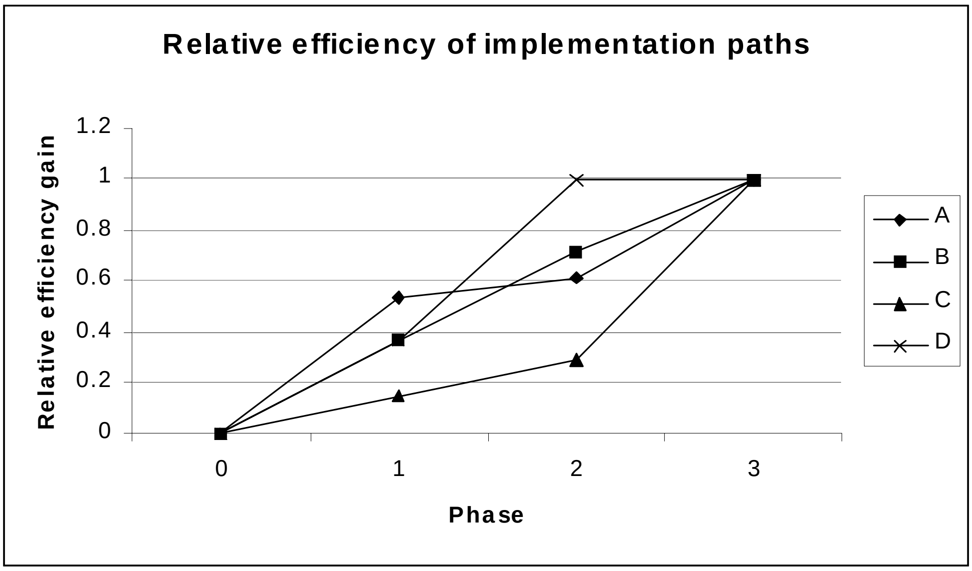

Figure 4.1 Relative efficiency along implementation paths in an illustrative small network mode

The example shows how strongly the time profile of net social benefits may vary between different implementation paths, even if they connect the same initial and end point, and even if we only consider implementation paths along which barriers are only reduced over time (implying monotonous patterns of efficiency gains over time).

4.2.3.2 Previous modelling exercises

Proost et al (2002) surveyed three recent EC studies (OPTIMA, TRENEN, AFFORD) that had dealt with second-best marginal cost pricing. Most studies concern land transport, and in particular urban road transport. First-best and certainly second-best studies on pricing of air and sea transport in Europe are very rare.

Most studies have used a common definition of economic efficiency but large discrepancies can be found in the definitions of external costs. Most of the time, equity issues are simply not considered. Most studies analysed pricing constraints in an on/off way. Different combinations of pricing constraints were compared but this is only one of the inputs into an optimal implementation plan. An optimal implementation plan needs to understand the barriers underlying the pricing constraints and needs to quantify the cost of removing the barriers and the optimal order and timing of doing this. None of the surveyed studies did this.

4.2.3.3 Modelling and Assessment Framework

In MC-ICAM, eight models were used in the case studies. The models are grouped as urban models and interurban models. The models have been developed using very different methodologies and have been calibrated to different cities and regions.

The four urban models (METROPOLIS, TRENEN, RETRO, MEPLAN-HELSINKI) include different dimensions of behaviour, evaluate outcomes using different measures of effectiveness, and are applied to different geographical areas. It should be evident they do not serve as substitutes but as complements. On the downside, none of the models is designed specifically to study the phases of implementation of marginal-cost pricing.

The interurban models used in MC-ICAM include SMILE, PINGO, SCENES and a small general equilibrium model. Some of these models contain a very detailed representation of the freight operations but do not have a good representation of externalities (e.g. congestion). Again none of these models is designed specifically to analyse an optimal implementation strategy.

We developed (in Proost et al, 2002) an assessment framework for second-best marginal cost based transport pricing reforms. Under the assessment framework we presented a set of rules that tell us:

- what effects are to be taken into account
- how to compute the effects
- how to value these effects
- how to aggregate the valued effects into an objective function
- how to use the objective function to rank alternatives

This assessment framework can be seen as a rigorous definition of a cost benefit analysis that includes efficiency and equity objectives. The list of basic effects on the transport market and their valuation, including the valuation of external effects, have become standard knowledge in the profession and can be taken from other EU projects. The main difficulty that remains are valuation of land use effects. Aggregation over time follows best current discounting practice (at government international borrowing rate) except for effects on future generations that may warrant another weight. Aggregation over individuals can be done using distributional weights.

The main technical problems that remain are the valuation of effects on non-transport markets. The correct assessment of alternative uses of the transport pricing revenues and the analysis of the full effects of freight pricing in an economy with distortions is a complex undertaking that goes beyond the capabilities of existing transport models and requires more experimentation. It has been shown that there is no simple solution for the marginal value of public funds.

5 KEY RESULTS FROM STUDIES OF BARRIERS AND CONSTRAINTS

A number of earlier projects including AFFORD, PATS and PRIMA have identified various barriers to pricing reform. MC-ICAM has continued this work, and has considered barriers to marginal cost-based pricing in relation to all major transport modes.

Drawing on the theoretical conclusions discussed above (part 3), MC-ICAM proceeded to seek to identify key barriers and constraints to implementation for urban and interurban road transport, and for urban public transport, rail, air and sea, using a mix of past literature, case studies of attempts at implementation and interviews with those responsible. We divided the barriers into three broad types introduced above (section 2.1) – technological and practical, legal and institutional, and acceptability. Our presentation of the key conclusions, in subsections 5.1-5.4, is organised under the following headings:

- Technological and practical barriers
- Legal and institutional barriers
- Acceptability barriers
- Conclusions and directions for further analysis of barriers and constraints

Under each heading barriers for both urban and interurban road and for non-roads modes (rail, air and water) are discussed.

5.1 Technological and practical barriers

Urban transport and interurban road

Marler et al (2003) concluded that for urban and interurban road transport, the big issue is cost and reliability of the technology and confidence that it will work rather than availability per se. However, we believe that availability of on-board vehicle equipment, which may be introduced for navigational or other purposes than pricing, will have a big impact and is likely to change the situation (including drivers' attitudes) radically in the future. For urban public transport, smart card technology is rapidly removing the technological barriers to full marginal cost pricing.

The other major technological issue that remains for interurban road pricing is inter-operability, where different countries are already proceeding with different technological solutions but where international movement particularly of freight vehicles makes inter-operability a crucial target. In summary, the following barriers to marginal cost pricing were identified:

– Technology for road pricing though in principle exists, is not widely tested and is likely to be considered too risky to justify full-scale implementation in the short term
– Interoperability problem in interurban road transport (HGVs in cross-border transport)
– Complex spatial structure of urban road networks and lack of space as important physical characteristics of urban areas
– Availability of reliable cost and other data and transferability of marginal cost and other estimates

Rail, air and water

For rail, air and sea transport technological barriers have never been very important. Rather than the technology, the biggest issue is devising appropriate ways of measuring the costs of congestion and scarcity of capacity and of reflecting these in charges. Adler et al (2003) defined the major technological and practical barriers as follows:

- Problems of measurement: estimation methods and, in most cases, estimated values exist for most cost components of marginal external costs, though the need for further research is especially acute for congestion and scarcity.

5.2 Legal and institutional barriers

Urban transport and interurban road

Marler et al (2003) concluded that fundamental institutional problems are related to the relationship between different levels of government. One important institutional barrier is that legislation both at the EU level and in many individual countries does not permit marginal social cost pricing. For instance the current Eurovignette Directive requires that charges be related to infrastructure costs and not external costs. Similarly there may be problems of co-ordination with other policies (fiscal, regional, land use, social etc) and their goals. Other than in the (very) short term, however, these problems often can easily be rectified – if desired.

Potential relevant legal and institutional barriers to the implementation of marginal cost-based road pricing may be related to the following themes:

- insufficient policy framework and supportive legislation at European level
- contradictory policy objectives and insufficient supportive legislation at national level
- insufficient co-ordination/co-operation and non-optimal organisational structures
- contradictory legislation and policies in other areas and sectors
- opposition by stakeholder/interest groups and opposition parties

Relating to these themes Marler et al (2003) identified the following key barriers:

- Subsidiarity principle in urban transport
- Lack of a common European strategy or framework for interurban roads
- Lack of European laws to support kilometre-based charging on interurban road freight (the proposed revision of the Eurovignette directive would remove this problem although it still does not permit full charging of externalities)
- Predominance of policy goals that are contradictory with economic efficiency and the principles of marginal cost pricing
- Lack of national laws to permit or facilitate marginal cost- pricing as a general policy approach
- Lack of national laws to enable price differentiation (over vehicles, over time and spatially)
- Lack of co-ordination/co-operation between neighbouring cities and communities (In some games waiting is advantageous and in other games there is a first-mover advantage. In the case of pricing reform it seems apparent that most cities prefer to wait and learn from the experience of others).
- Disconnected nature of the decision-making structures & processes for urban transport and interurban roads
- Multiple administrative levels involved in formulating and implementing pricing policy, with responsibilities and powers defined and assigned incompletely or non-optimally
- Supply and operation of private non-residential parking and franchised or deregulated public transport services outside direct government control
- Public-Private-Partnership (PPP) for funding, producing and operating infrastructure

- Legislation to prevent direct charges for road use with reference to freedom of access and movement and certain civil liberties and privacy needs
- Contradictory legislation related to fiscal taxation
- Opposition by non-governmental stakeholder/interest groups and opposition parties

We concluded that in relation to legal and institutional issues in urban transport and on interurban roads, the real issue is the acceptability of the necessary actions – legislation and of the goals of marginal cost pricing, and where needed willingness to adjust other policies and their goals accordingly.

Rail, air and water

Adler et al (2003) identified the key legal and institutional barriers for rail, air and water transport as follows:

- Anti-trust legal problems: Currently there are legal problems with the implementation of two-part tariffs in the rail sector. To overcome this it will be necessary either to change the laws or adopt a different mechanism design.
- Failure to provide correct incentives for investment: There is a fear that the application of marginal cost pricing (MCP) may provide poor incentives for capacity expansion where needed, as well as causing X-inefficiency. The EC Directive on infrastructure charges (2001/14) recognises these issues by permitting non-discriminatory mark-ups above marginal cost (MC) for financial reasons and to recover the costs of specific investments and by requiring studies of capacity expansion where scarcity charges are levied.
- Failure to encourage competition within and across modes: the most likely second best policy involves two part tariffs and/or Ramsey pricing, but this may not be possible to do in a way that preserves terms of competition between operators. Furthermore, if other modes of transport charge less than MCP, for example road, this may cause rail to lose competitiveness.

5.3 Acceptability barriers

Urban transport and interurban road

Marler et al (2003) concluded based on the reviews and analyses undertaken in MC-ICAM that, both in urban transport and on interurban roads, the key barrier is acceptability, public and political. Even at the heart of the identified technological and institutional barriers the real issue is often acceptability. Indeed, key questions are: Do politicians and the public trust the technology? Do they facilitate or promote the development of necessary technologies? Do they accept the need for institutional reform? And so on.

Rail, air and water

Adler et al (2003) identified the key acceptability barrier for rail, air and water modes to be:

- Governments are unwilling or unable to provide necessary subsidies: under MCP with scale (and/or density and/or scope) economies, there is a need to subsidise as a charge above MC would otherwise deter users without saving on costs, but this may be unacceptable politically. It may be considered equitable to charge according to MCP but governments may fear X-inefficiency resulting from subsidisation.

5.4 Conclusions and directions for further analysis of barriers

We now, in subsections 5.4.1-5.4.4, present our conclusions and suggested directions for further analysis of barriers and constraints under the following headings:

- Comparison between different modes
- Relative importance of barriers
- Linking key barriers and their implied constraints
- Interdependencies as challenge for research and policymaking

5.4.1 Comparison between different modes

We have aimed to provide a comprehensive picture of the relevant barriers and constraints, rather than going into in-depth analysis in individual cases. This objective of research was motivated by the fact that many other research projects and demonstrations already have produced numerous detailed local and country specific analyses of potentially important barriers and constraints and related issues. We have drawn on these projects and demonstrations as reported in the parallel thematic network (imprint-Europe) and discussed the barriers and constraints with relevant policy makers rigorous scientific demonstration of barriers and constraints. More work is needed on this issue. While these accounts have provided extremely valuable information, they as such hardly can provide for a satisfactory policy analysis.

The barriers to pricing are reasonably similar in nature for rail, air and water modes. This is evident because these non-roads modes of transport are similar in the sense that they work through networks with stations or ports and generally a hub-and-spoke system. Acceptability is a smaller problem in rail, air and water sectors than on roads. On the other hand, a number of factors make acceptability less of a barrier in interurban road transport than in urban transport. One is the difference in the complexity of the transport network: urban networks can be much more complex. Another key factor is that, in urban transport the users are mainly private car drivers; in interurban road the main user group are companies, which can pass the costs over to the consumers. A third factor the widespread desire for pricing reform, amongst road freight industry participants in many countries, in order to overcome the problem of the current system that the taxes paid (and the revenues received) depend on where the vehicle is registered and fuelled rather than where it travels. This provides an opportunity for implementation in interurban road transport that does not seem to exist in urban transport.

5.4.2 Relative importance of barriers

Having identified the range of potential barriers and barrier types, a natural next question to ask is: Is it possible to conclude something about their relative importance? No doubt one can suggest plausible answers in specific applications to individual cities and countries. When considering this question on a general or analytic level, an obvious key observation is that barriers can have impact on policy implementation i.e. can become real or effective, only through the constraints they imply on the different aspects (key dimensions) of the pricing policy (system) considered. In order to identify the most important underlying barriers it is first necessary to identify the most important constraints. The situation can easily be complicated, as evidently in practical situations a large number of factors are simultaneously at work. And the situation can vary between localities (countries, regions, cities). In light of this, what is said here can only be tentative and indicative.

As for the technological barriers, as said above, they are no big issue in rail, air and water transport. They are more relevant in road transport. But, we believe, these can nowadays be no reason not to introduce road pricing – if not in a full scale then at a smaller scale at least. A sufficient technology certainly exists, and at a reasonable cost. Although the technological barriers are likely to cause serious problems to the application of marginal cost-based road pricing in its full scale and with full differentiation in the short term, in the medium term and undoubtedly in the long term they should be no hindrance to full-scale applications.

More or less similar comments apply to legal and institutional barriers. Although these kinds of barriers certainly are important to take into account, they in themselves can hardly be a convincing argument for not introducing road pricing except in the very short term. New laws can always be passed and in many cases in a relatively short time (as is often seen), if only a clear need existed. And institutional and organisational structures can always be changed, although in many cases it is realistic to think of gradual changes only due to the complexity of the issues.

These kinds of conclusions regarding the identified technological/practical and legal/institutional barriers and issues necessarily lead one to the view that the 'true' barriers for road pricing are acceptability related. Acceptability, public and political, clearly appears to be the greatest source of barriers to marginal social cost pricing in road transport. This necessarily leads one to consider the lack of political will. One potentially important factor at work is the potential interdependence between the low socio-political acceptability and the legal and institutional status quo. For instance, prevailing political and financial relationships between local and national governments as well as between different political parties may make fundamental decisions about charging and revenue use more to do with politics than economics. This means that marginal cost pricing principles (as purely economic principles) are easily over-ruled in political and intersectoral decision-making, particularly where one level of government is likely to lose out financially as compared to another (or one party to lose out politically as compared to another). Also, in many cases the personal interests of government workers may be biased in favour of continuing existing policies. They – whether directly responsible for the implementation or indirectly affected by it – either may not understand or agree with the new policies or may be afraid of likely organisational rearrangements and even losing their jobs.

Based on the available research and empirical evidence, we concluded that, the acceptability barriers may be the most difficult to deal with, the technological and practical barriers the easiest, and the legal and institutional barriers in between. Table 5.1 illustrates the situation, by showing whether the identified barriers typically allow (or prevent) partial or full-scale application of marginal cost pricing in the short, medium and long term.

Table 5.1: Relative importance and likely development of barriers over time

	Short term (0-3 years)	Medium term (3-10 years)	Long term (10- years)
Technological / practical barriers	Only partial application possible	Full scale application possible	Full scale application possible
Legal / institutional barriers	Only partial application possible	Only partial application possible	Full scale application possible
Acceptability barriers	No partial application possible	Only partial application possible	Full scale application possible

However, while presenting this streamlined picture, we need to emphasise that, on a general level like this, one should not (and cannot) go too far in drawing conclusions on the relative or absolute strengths of the different barriers or barrier types. First, their importance can greatly vary between countries and localities. Indeed, evidently, any attempt to provide sensible generally valid orderings in any more detailed level than suggested in table 4.5 may be precluded by the potentially great differences between different countries (and cities). This is because different countries may be at the different levels of technological and economic development; the legal and institutional frameworks can be, historically and due to different political systems, very different; and so on.

Another reason why clear-cut conclusions concerning the relative or absolute importance of the different barriers and barrier types are not possible is that barriers operate through constraints and in order to be able to rank barriers we need to investigate the link through constraints first. A third reason is potentially strong interdependencies that exist between them. These last two issues are discussed next.

5.4.3 Linking key barriers and their implied constraints

The discussion above highlights the great uncertainty that remains about the exact nature of the barriers and constraints and the link between them. Understanding the degree to which the barriers and constraints can be eased over time is necessary for determining what government actions can help with this.

Table 5.2 illustrates the nature of the relationship between the whole range of the identified barriers (on the left) and their implied constraints (shown on the top). As stated above, these relationships are causal (that's why the constraints are 'implied'). Many of the elements of the table are highly debatable, and therefore the table should only be seen as indicative. The presentation does not claim to be comprehensive either: important factors may be missing. But the table includes typical elements that were believed to be common enough to be considered as relevant in most applications. The items need to be specified in more detail for each practical application (city, urban area, region, corridor, country, group of countries etc).

Evidently, a table like 5.2 can serve as an invaluable blueprint – when appropriately developed to contain all information relevant to the practical application in question (city, urban area, region, transport corridor, country, group of countries etc). It can help analysts and policymakers (or planners) to be able to identify potential barriers and constraints and to determine the phasing of the removal of underlying barriers in practical terms: which barriers should be removed, and in which order, in order to relax a given constraint. And it highlights the importance, in any practical application, of considering both barriers and constraints and the interplay between them.

Table 5.2: Barriers vs implied second-best constraints

Implied second-best constraints on Underlying barriers	Coverage or scope of the pricing system	Composition and level of pricing	Degree of differentiation of pricing measures	Rules and principles governing revenue use	Use of supplementary non-price measures
TECHNOLOGICAL/PRACTICAL					
1. Technology for road pricing though it in principle exist, is not tested in a broader scale and is likely to be too risky to justify full-scale implementation in the short term	Not all links tolled Only central areas tolled in urban transport Only main links tolled in interurban transport Constraints on which externalities can be charged for	Fixed charges still important	Flat tolls over time and space Undifferentiated tolls over user groups	-	-
2. Interoperability problems in interurban road transport (HGVs in cross-border transport)	Only main links tolled in interurban transport European wide kilometre charge delayed	-	-	-	-
3. Complex spatial structure of urban road networks and lack of space and related physical characteristics of urban areas	Only central areas tolled in urban transport. Also danger of making mistakes; e.g. expanding capacity of a link subject to Braess paradox.	-	-	-	Fixed capacities and given network configurations (insufficient space for expansion in historic city centres; difficulty of building a new essential link of a cordon due to environmental reasons (parks, historical cites).
4. Availability of reliable cost and other data and transferability of marginal cost and other estimates	Only central areas tolled in urban transport Only main links tolled in interurban transport Constraints on which externalities can be charged for Similar to #3, danger of mistakes. May dictate setting tolls conservatively.	Simple charging systems	Flat tolls over time and space Undifferentiated tolls over user groups	-	-
LEGAL/INSTITUTIONAL					

5. Subsidiarity principle in urban transport	Not all links tolled Only central urban areas tolled Depends on which lower level government has mandate to set tolls, and also whether that level refuses to.	-	-	-	-
6. Lack of a common European strategy or framework for interurban roads	No uniform pricing throughout all Europe This sounds like relaxation of a constraint.	Pricing schemes non-harmonised	-	-	-
7. Lack of European laws to support kilometre-based charging on interurban road freight	Only main links tolled in interurban transport. Not all user groups tolled Constraints on which externalities can be charged for	Specific price caps	Flat tolls over time and space	-	-
8. Predominance of policy goals that are contradictory with economic efficiency and the principle of marginal cost pricing	No road charging	Fixed charges popular	Flat tolls over time and space Undifferentiated tolls over user groups Not obvious why these constraints would apply.	Revenues to state budget	-
9. Lack of national laws to permit or facilitate marginal cost-based road pricing as a general policy approach	No road charging	-	-	-	-
10. Lack of national laws to enable price differentiation (over vehicles, over time and spatially)	-	-	Flat tolls over time and space Undifferentiated tolls over user groups	-	-
11. Lack of co-ordination/co-operation between neighbouring cities and communities (e.g. ‘strategic wait’)	Not all links and not all urban areas tolled Only central urban areas tolled	No integrated pricing system possible	-	Revenues hypothecated	Impossibility of setting local technology standards in combination with non-differentiated taxes
12. Disconnected nature of the decision-making structures & processes for	Not all links and not all urban area tolled Only central urban areas tolled	Charges to be revenue neutral: need to lower fuel taxes and vehicle excises to	-	Revenues hypothecated (because in practice there would be no	Can’t expand transit capacity using toll revenues

urban transport and interurban roads		compensate Wouldn't offsetting reductions in fuel taxes be less likely if a national govt doesn't cooperate with a local govt?		cross-subsidisation of public transit by roads or vice versa)	
13. Multiple administrative levels involved in formulating and implementing pricing policy, with responsibilities and powers defined and assigned incompletely or non-optimally	No road charging	-	-	-	-
14. Supply and operation of private non-residential parking and franchised or deregulated public transport services outside direct government control	No pricing of privately provided parking.	Public transport charges based on commercial not marginal social cost principles	-	Revenues hypothecated	-
15. Public-Private-Partnership (PPP) for funding, producing and operating infrastructure	Private funding may enable, or accelerate, tolling. Examples in North America are Highway 407 in Toronto and State Route 91 in California.	Road charges based on commercial not marginal social cost principles. Tolls could be subject to price cap or rate-of-return regulation.	Privatisation may relax acceptability constraints on differentiation; e.g. by time of day.	Revenues hypothecated	-
16. Legislation to prevent direct charges for road use with reference to freedom of access and movement and certain civil liberties and privacy needs	Not all links tolled Only central areas tolled in urban transport	Traditional fixed charges possible, not new variable charges	Tolling may be restricted to covering costs of supplying infrastructure. If so, differentiation by vehicle size, emissions, etc., won't be allowed. Undifferentiated tolls over user groups	-	-
17. Contradictory legislation related	-	Fiscal taxes	Flat tolls over time and space	Revenues to the state	-

to fiscal taxation				budget No revenue hypothecation	
18. Opposition by stakeholder/interest groups and opposition parties	Constraints on which externalities can be charged for Need for pilot / demonstration schemes	Specific price caps	-	Need for revenue hypothecation	Capacities may need to be expanded
ACCEPTABILITY					
19. Low public acceptability	No road pricing or at best only simple schemes possible Constraints on which externalities and user groups can be charged for Need for experiments and pilot and demonstration schemes Need for using parking pricing as substitute for road pricing	Only traditional fixed charges possible, not new variable charges Specific price caps: the system must not make the poor or some other key groups worse off	Flat tolls and public transport fares over time and space Undifferentiated tolls over user groups Differentiation not possible (except through fixed charges)	Need for revenue hypothecation for a popular cause (for improving road travel conditions and / or providing appropriate alternatives)	Need for information provision campaigns and systems Need for earmarking Need for capacity expansion (as a carrot), using hypothecated revenues Charges to be revenue neutral (acceptability): need to lower fuel taxes and vehicle excises to compensate Need for subsidies Improvement of public transport services
20. Low businesses acceptability	Need for pilot / demonstration schemes	Specific price caps	-	Need for revenue hypothecation	Cooperation with neighbouring communities / cities and countries
21. Low political acceptability	No road charging	-	-	Revenue hypothecation	-

5.4.3.1 Interdependencies as challenge for research and policymaking

Another complication is the obvious interdependence between different barriers and barrier types. For example, on a general level, acceptability depends on the existing technology and on the legal and institutional status quo. On the other hand, acceptability affects these. Technological development (or lack of it) may be dependent on the prevailing legislation and institutional/organisational structures. While in many cases changing the legal and institutional structures first might be the key to gaining the required socio-political acceptability, such changes do not appear likely without gaining the required acceptance first. And so on. Obviously there is a 'vicious circle' between the three barrier types that needs to be allowed for in any realistic model and analysis. The situation is illustrated in Figure 5.1.

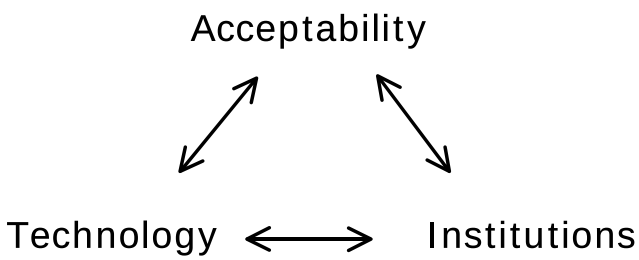

Figure 5.1 'Vicious circle'

These important interdependencies have not received much attention in the literature. Clearly they are a real challenge for policymaking and research. For example, the interdependencies:

1. may make a structured analysis of barriers very difficult. It is easy to imagine that analytic problems may become rather complicated if a formal analysis using a formal mathematical model is attempted.
2. may make straightforward comparison of the relative (or absolute) stength of individual barriers or barrier types is not very useful. Evidently, no clear practical policy conclusions would be able to derive from such comparisons anyway.
3. may make the removal of barriers (and hence of constraints) more difficult than if these were only isolated problems. Evidently, different and more comprehensive strategies for their elimination are needed than if they were only independent and easily isolated problems.
4. be an important reason for the implementation of marginal cost pricing to be so difficult – much more difficult than if relevant barriers were isolated phenomena/factors.

In particular, the last two conclusions suggest that, besides many identified simpler barriers, a big 'umbrella' barrier hovering over the implementation is the vicious circle between technology, institutions and acceptability. New technological developments and solutions would be important for acceptability. But such developments and solutions (e.g. investments, possibilities for testing the technologies) are very much dependent on and hampered by the current institutional conditions. Thirdly, there is the interdependence between political acceptability and institutional status quo.

In order to be able to get over the interdependencies (break the 'vicious circle'), it may be useful to try to understand why they are there in the first place. There may be several explanations for why the barriers are so intertwined. One candidate may be the existing political structures – the apparent dependence of many barriers on the inherent structural workings of a representative democracy and decision-making system. These issues however have been beyond the scope of the current study.

In particular, the MC-ICAM modelling case studies to be discussed next were not able to address these issues. They treat barriers and constraints, and the phases of implementation, as well as the relevant instruments at each phase, as exogenous.

6 MODELLING CASE STUDIES ON IMPLEMENTATION PATHS

6.1 Case studies on modelling urban transport

6.1.1 Case cities and models

In urban transport the focus was on four cities: Paris, Brussels, Helsinki and Oslo. Each city used its own model. TRENEN (used for Brussels) is best suited to conduct first-best analysis and to account for revenue allocation. The strength of RETRO and MEPLAN (used for Oslo and Helsinki respectively) is that these models include land use, and can capture long-term changes in location choice and urban structure. The primary strength of METROPOLIS (used for Paris) is its fine level of spatial and temporal disaggregation, conferred respectively by its ability to handle large-scale road networks and to track the evolution of traffic flows on a second-by-second basis.

All case studies examined phased implementation paths in which constraints on the set of pricing instruments and accompanying policy measures were progressively relaxed. And all but the Brussels study examined paths with four time periods: a reference scenario that describes the status quo, two intermediate phases or stages, and a long-run or final phase.

In all studies, the sets of instruments and the constraints were treated as exogenous at each phase. However, the studies differed in the assumptions they made about what instruments are available and what constraints are applicable. These assumptions were based on detailed knowledge of the case study areas and the personal judgments of the case study leaders, and it is difficult to explain the choices on the basis of simple, general rules. The case studies also differed in other important ways: the models used, the endogenous dimensions of traveller behaviour, whether land use decisions are considered, the level of detail in which road and public transit networks are represented, and the accuracy with which first-best or second-best policies were computed. The case studies also differed in their treatment of excess burden. The Paris study adopted as a base case the “official” value used for planning in France of 0.14 for the marginal cost of public funds. The other three case studies all assumed a zero value.

Because the models included distinct sets of dimensions of behaviour, and evaluated outcomes using non-identical sets of measures of effectiveness, it was evident that they were not perfect substitutes. Each model has its unique strengths that were reflected in the different questions that the case studies addressed.

Paris

The Paris case study concerned road pricing in the Ile-de-France area, which includes Paris Intra Muros, the suburbs and the new towns around Paris. Simulations were undertaken using the dynamic network equilibrium model METROPOLIS, which treats as endogenous individual choices of mode, departure time and route. Implementation of road pricing over the period 2002-2012 was assumed to unfold in four phases (Phases 0-3) as technological, legal/institutional and acceptability barriers were gradually relaxed. Three road pricing instruments were considered: link-based tolls on individual highways, cordon tolls in and around the city centre, and a time-based tax that was calibrated as a percentage increase in the fuel tax. Two variants of the link-based tolls and cordon tolls were considered: flat or time-invariant tolls, and modular tolls with peak and off-peak levels.

Brussels

The Brussels case study focused on two types of barriers that arise in the design and execution of optimal implementation paths for marginal-cost pricing. The first barrier are constraints on the usage of policy instruments, and the second arises with multiple levels of government that differ in their objectives and powers. The model TRENEN II-URBAN ("TRENEN") was used to examine both obstacles. TRENEN is designed to compute optimal policy values (tolls, public transport fares, etc.) while taking into account various constraints. TRENEN is a strategic model that provides a very simple representation of all modes of transport. In particular it represents a city road network via a single aggregated speed-flow relationship. To study constraints on the usage of policy instruments, combinations of three policy instruments were examined: parking fees, public transit fares and electronic road tolls.

To explore problems that can arise with multiple levels of government, the case study was concerned with the decisions of two different levels of government, city and regional, on different charging instruments, and the implications for economic efficiency of alternative distributions of authority between the two levels. Two alternative scenarios were considered. In the first scenario each level of government does what is best for its electorate taking as given the decisions of the other level, thereby leading to a Nash equilibrium. In the second scenario leading to a Stackelberg equilibrium, the regional level moves first, and the city government does what is best for its electorate given the previous decisions of the regional level. Attention was limited to parking fees and a cordon toll as policy instruments. The city government was assumed to choose the level of parking fees inside Brussels, while power to set the cordon toll resides with the regional government – which has authority over a wider group of the population including Brussels. Both levels of government were assumed to behave benevolently on behalf of their constituents. The city government was assumed to maximise welfare of the city inhabitants, and the regional government to maximise the welfare of both inhabitants and commuters.

Helsinki

The Helsinki case study covered an area that includes the Helsinki Metropolitan Area and several surrounding cities. Simulations were carried out using MEPLAN, a comprehensive land-use and transport interaction modelling package that was already set up for analysis of the region. (The 5-year stepping version of the MEPLAN model was tested and analysed for the first time in the MC-ICAM project.) Various alternative implementation paths for transport pricing in the area were computed and compared over a 15-year time horizon from 2005 to 2020. Policy instruments considered were a cordon toll, distance-based tolls, fuel taxes, parking fees, public transport fares and accelerated transport capacity investments.

The basic implementation path encompassed the status quo (Phase 0), and three stages of pricing reform (Phases 1-3) that feature progressive increases in the petrol tax, and progressive decreases in public transport fares. Radial/cordon peak road tolls in the metropolitan area were introduced in Phase 2, and these were replaced by distance-based peak tariffs in Phase 3.

Oslo

The Oslo case study used a modelling framework that includes three components: (1) a real network land use and transport model (RETRO), (2) a cost benefit framework for evaluation of transport pricing strategies, and (3) an optimisation method for derivation of marginal social cost pricing strategies. This framework was used to evaluate the effects on transport activity and land use of phasing in marginal social cost pricing of passenger transport in the Greater Oslo area over a 28-year time horizon. All major modes were included; i.e. private car, public transport and slow modes (walk/bicycle).

Four implementation paths were constructed by considering alternative scenarios regarding fuel taxes on CO_2 emissions, and technological and legal barriers that impose constraints on the pricing measures available for MSCP. Toll charges and public transport fares were constrained by upper and lower limits on fares, an upper limit on inter-zonal inequity, and a lower limit on present value of finance.

6.1.2 Applicability of the urban models

6.1.2.1 First-best analysis, second-best analysis and simulation of arbitrary policies

Of the four urban models, TRENEN is the most suited for first-best analysis because it is a normative model with an explicit welfare-economic framework, and because it is designed to identify optimal policies. And since TRENEN can optimise subject to any set of constraints on pricing and revenue allocation, it is also well designed for second-best analysis.

First-best and second-best analysis is less straightforward with the other three models. In part, this is because they are not designed to identify optimal policies, and in part because (unlike TRENEN) these models are applied to large-scale road networks, and computation time is a constraint. Nevertheless, with RETRO a constrained optimisation method is feasible for assessment of first- and second best analysis. Moreover, second-best and first best instruments can be optimised in combination. However, first-best analysis with RETRO is limited to the possible marginal cost pricing mechanisms that can be included as part of the road link functions of the EMME/2 real network representation of Greater Oslo. (For this reason, RETRO is granted a higher score in Table 1-1 for second-best than for first-best analysis.) This also applies to Helsinki Model.

6.1.2.2 Accounting for the rest of the economy

As a quasi-general equilibrium model,[1] TRENEN is well structured to account for interactions with the rest of the economy. This is also a strength of RETRO and MEPLAN in that these models include land use. However, to be comparable all the urban models require values for the marginal cost of public funds (MCPF). Identifying applicable values for MCPF even approximately is difficult because MCPF depends on a number of factors that vary across case study sites, including the deadweight loss incurred from raising revenues through income and other taxes, on other local economic distortions, and on how transport revenues are used.

The case studies adopt different base-case values for MCPF. For Brussels, Helsinki and Oslo, MCPF is set to zero.[2] For Paris, it is set at the “official” value of 0.14. Previous studies (notably the AFFORD project) have shown that the value chosen for MCPF can influence strongly both the optimal choice of policy instruments and the estimated welfare gains derived. This should be kept in mind when assessing the results of the urban case studies reported here.

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[1] TRENEN is a quasi-general equilibrium model because the labour supply is kept fixed and the product prices of consumption goods (other transport) are kept fixed.

[2] In the public finance literature the Marginal Cost of Public Funds (MCPF) is defined to be the gross efficiency cost of raising an additional unit of tax revenue. Some sources also define it as the gross welfare cost minus 1. In Proost et al (2002), it has been shown that the MCPF depends crucially on how the revenues of transport taxes are used.

6.1.2.3 Analysing phasing of implementation and best phasing

None of the models is specifically designed to study the phases of implementation of marginal-cost pricing. RETRO is perhaps the most suited because of its capacity to simulate short-, medium- and long-run time horizons with successively larger sets of endogenous dimensions of behaviour. But even RETRO is not set up to determine the optimal adjustment path through the various stages of adjustment.

The models differ with respect to the interdependence of optimal policies and welfare across time periods. METROPOLIS and TRENEN are a-temporal in the sense that policies/actions taken in one period do not affect the values of state variables, or the constraints facing users or policy makers, in future periods.[3] But in MEPLAN, and in a more restricted sense also RETRO, path dependence is present because of irreversibility in land-use decisions and regulations. This is a complicating factor in the analysis and choice of implementation paths in the Helsinki and Oslo case studies.[4]

It is possible with all the models to simulate the effects of a succession of policy packages that incorporate progressively more instruments and/or more finely-tuned instruments. But the administration costs of implementing and operating the various instruments are not automatically accounted for in any model, and obtaining accurate information on these costs is likely to be difficult — particularly for technologies that have not yet been implemented anywhere in the world, and that may yet be only at the conceptual stage of development.

6.2 Simulations

6.2.1 Benchmark scenarios

The benchmark scenarios include a base-case scenario (typically the status quo, or do-nothing), and the first-best optimum.

Base-case scenario

Each case study provides a base case that serves as a benchmark for comparison with other scenarios and for sensitivity analysis. The base case is designed to describe either the *status quo*, or (for applications to future periods) a set of policies or do-minimum strategies that are anticipated in the absence of policy reform. The base case uses empirical input data, and produces outputs that are compared with corresponding empirical data, as well as used to compute a set of measures of effectiveness.

For the base-case scenario, equilibria and optima are computed as accurately as possible to evaluate the sensitivity of output to computation time and the number of iterations of the algorithm that is used. Documentation on the speed and reliability of convergence to an equilibrium or stationary state is provided.

First-best optimum

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[3] In the case of TRENEN, path dependence is absent because policy instruments are always set at their optimal values. All state variables (including stocks of road vehicles and public transit vehicles) as well as agent behaviour are fully optimised with respect to market prices (see Proost et al (2002), Section 3.4).

[4] An example of path dependence is presented in the Helsinki study.

Each case study provides a definition of the first-best optimum appropriate to the context of the case study setting and the model used. A description of how the first-best optimum is computed is also given.[5]

6.2.2 Alternative policy scenarios

Alternative policy scenarios include various second-best policies, policies that may presently be under consideration for the case-study area, and arbitrary policies that may be useful as part of the sensitivity analysis. To construct an optimal implementation path for marginal-cost-based pricing, a sequence of such scenarios is simulated.

Second-best scenarios

Examples of second-best pricing instruments include cordon tolls, link-based tolling on a subset of the links that comprise a road network, and step tolls or other imperfectly flexible time-varying toll schemes. Values for these and other instruments can be set according to several alternative rules:

- Quasi first-best pricing[6]. This entails the naïve application of marginal-cost pricing rules that ignore second-best distortions (c.f. Niskanen et al, 2003a).
- Average-cost based pricing (c.f. Marler et al, 2003, Section 3.1). Average-cost pricing may be legally required by self-financing constraints, or deemed necessary by political or social acceptability pressures to respect the user-pays principle.
- The rules defining the two hypothetical policy packages that were investigated in the AFFORD project (Milne et al, 2000). These packages were: (1) a weak package (acceptable package), that featured low charges and earmarking of revenue use, and (2) a strong package (best practice second-best case) with high charges and no hypothecation of revenue (c.f. Marler et al, 2003, Section 4.5.1).

The execution of each second-best optimum (SBO) scenario follows the same guidelines as for the first-best optimum, and includes:

- A clear explanation of the policy measures used to implement the SBO, including any changes in parameter values such as user costs.
- An explanation of how the equilibrium/optimum is computed (if in a different way from the FBO).
- Impacts on welfare and assorted MOE.
- Statistics on the extent to which each externality is internalised.
- Sensitivity analysis.

Policies under consideration

[5] In the case studies with complex networks (e.g. Paris) it is not possible to compute an exact first-best optimum, and an approximation is used instead.

[6] Sometimes referred to as third-best pricing.

The guidelines for second-best scenarios apply to this class of policies too. Where the simulation of real-world policies requires "interpretation" or "translation" to fit the model, the assumptions and specification are described and justified in detail.

6.2.3 The implementation path

Formulation of implementation paths

Implementation paths are defined by the course taken from the starting point to the ultimate state or scenario in which a first-best optimum may or may not be reached. In light of various uncertainties about the future, and also to economise on computation time, the paths considered comprise a small number of stages; *e.g*. short, medium, and long-run time horizons. The stages are defined by what variables are endogenous, constraints on policy instruments, and so on. Comprehensive marginal-cost pricing is currently not feasible because of constraints originating from technological, institutional and acceptability-related barriers. As time passes, these constraints will generally (although not inevitably) be relaxed. The specification of short, medium, and long-run scenarios — or any other sequence of time periods — is chosen (and justified) on the basis of such constraints as they apply to the particular case study area.

Any given set of constraints defines a set of feasible implementation paths. Typically, the constraints are not so binding or onerous as to define a unique path. Consequently, a choice between alternative feasible paths must be made. The complexity of the case study models and the computation time required governs whether the implementation paths considered are optimal conditional on the constraints (*i.e*. second-best optimal), whether they are only approximately optimal because of computation time limitations, or whether the search for a “best” implementation path has to be restricted to a small set of paths essentially based on judgement.

Revision of plans over time

Intertemporal plans or strategies can be classified as either open loop or closed loop. An open-loop plan determines at the beginning of the planning period a sequence of *actions* to be taken according to a fixed calendar or schedule regardless of how well the policy has performed up to that point, and regardless of whether unforeseen circumstances develop that would have made an alternative sequence of actions a better choice. By contrast, a closed-loop plan entails a set of *decision rules* that prescribe actions to be taken as a function of the state reached (as well as the experience gained and other information acquired) when the time comes to implement the action.[7] For example, it may be worthwhile to toll a particular road only if daily usage exceeds a threshold value. If a closed-loop strategy is followed, tolling will be implemented when, and only when, this threshold is met.

Closed-loop strategies are generally superior to open-loop strategies when the future is uncertain — at least in games against nature rather than against other human players. But, to the best of our knowledge, closed-loop strategies for transport pricing have not yet been characterised theoretically in the literature, let alone solved numerically. A necessary first step in the formulation of such strategies is to analyse and understand the impacts of open-loop plans, and this is the approach taken in the urban case studies.

Path dependence and regret

[7] On this see Arnott (2002).

The implementation paths examined in the case studies are defined by sequences of time periods or stages. In each period, policy instruments are deployed conditional on the constraints prevailing in that period. The constraints are treated as exogenous, and values for the policy instruments are selected to be (more-or-less) optimal for that period without accounting for their possible consequences for future periods. This approach is necessitated by theoretical, practical and computational considerations as discussed in earlier workpackages. Nevertheless, it should be kept in mind that in reality choices/actions taken in one period affect constraints, choices and/or payoffs in future periods. Because of interdependencies between periods, the implementation path itself is characterised by path dependence. Interdependencies can arise in the MC-ICAM context for at least three reasons:

1. Lags in adjustment to changes in opportunity sets, prices, and other determinants of the generalised cost of travel. Adjustment lags can be substantial in the case of vehicle ownership, location choice, and land-use decisions. Depending on the duration of the lag relative to the length of the time period chosen for modelling purposes, the policy selected in period *t* will influence user choices not only in period *t*, but also in future periods.
2. Choices for certain policy instruments are either irreversible, or reversible only at some cost. This is obviously the case for investments in roads and other transportation infrastructure. It is also true for investments in toll-collection technology and administration procedures.
3. Political and acceptability constraints to marginal cost pricing are not set in stone, but depend on experience with pricing, and are therefore endogenous to the timetable chosen for the implementation path. In practice, this dependence may prove to be of great importance for successful introduction of marginal cost pricing.

The possibility of path dependence for reason 3 is ignored in all models. In terms of path dependence for reasons 1 and 2, the two models without land-use decisions (METROPOLIS and TRENEN) differ from the two models that include land use (MEPLAN and RETRO). Such dependence is absent from METROPOLIS because (a) none of the dimensions of behaviour endogenous to METROPOLIS are subject to adjustment lags, and (b) road capacities and other state variables are treated as fixed. TRENEN also ignores such dependence because prices are always set at optimal values, and since user behaviour and the values of all state variables — including stocks of road vehicles and public transit vehicles — are fully optimised with respect to prices (see Proost et al, 2002, Section 2.4.6).

As far as MEPLAN, complete adjustment within the five-year periods of the stepping model is assumed to take place for location choices, but not with respect to land-use regulations, building stocks, or transport infrastructure. And in RETRO, responses to changes in land-use decisions are assumed to play out over a period of 17 years. Linear interpolation is used to set values for policy instruments over the periods 2002-2015 and 2015 to 2030. The two land-use models MEPLAN and RETRO therefore embody appreciable “inertia”.

One possible consequence of path dependence that is of obvious policy significance is that choices that appear to be optimal in the early stages of implementation may turn out to be sub-optimal later on and regretted. One plausible example is an early (and irreversible) investment in cordon tolls that is subsequently made obsolete by the introduction of more flexible link-based electronic road pricing. Early investments in road capacity that turn out to be unwarranted once comprehensive road pricing is implemented, and traffic volumes are reduced, are another example.

The implementation paths for the four urban cases are now summarised; Tables 6.1 to 6.4 below give the information in tabular form.

6.2.4 Case study implementation paths

The Paris (Ile-De-France) Case Study

The implementation path for Paris consists of the status quo in 2002 (Phase 0), and three phases (1-3) corresponding to 2005, 2008, and 2012. In Phase 0 tolling is restricted to one or two of five roads: four Autoroutes leading into Paris and a ring road around the centre. Tolls are set at low levels in order to reduce the probability and/or intensity of political opposition to charging in the early stages of implementation. In Phase 1, all five roads are tolled and the objective is shifted from acceptability to efficiency. In Phase 2, tolling of the roads is abandoned and a cordon around the city centre is introduced. The charge incorporate limited time variation in the form of a single step (peak and off-peak). Finally, in Phase 3 a second outer cordon with the same time step is added. In addition, a time-based tax — which is calibrated on the basis of given percentage changes in the gasoline tax — is added to the set of policy instruments. When jointly optimised, the two cordon tolls and gasoline tax are able to support an approximate first-best optimum with respect to choices of mode, departure time, and route.

As noted earlier, METROPOLIS does not account explicitly for the usage of revenues. To capture possible double-dividend type benefits that accrue from revenues, the marginal cost of public funds is set throughout the implementation path at 0.14, which is the officially approved value for France.[8]

The Brussels Case Study

The case study for Brussels focuses on two types of obstacles that arise in implementing marginal social cost pricing. One obstacle, which is common to the other case studies, are constraints on the use of policy instruments. Some policy instruments may not be available immediately because of technological reasons or because of high implementation costs. The case study examines what individual instruments can contribute to a more efficient transport situation by successively adding them to a policy package. In this part of the case study one government is assumed to set all policy instruments in an optimal way.

The second obstacle to be examined arises with multiple levels of government that differ in their objectives and powers. Two instruments are considered: parking fees and a cordon toll. The Brussels city government is assumed to set the parking fee with the objective of maximising the well being or welfare of the city inhabitants. And the regional government is assumed to set the cordon toll to maximise the combined welfare of city inhabitants and commuters to Brussels. While this second obstacle is rather different from the first obstacle, it is highly relevant to the case study area. Moreover, disagreements between governments in objectives and competition for revenues are problems endemic to cities in Europe and elsewhere, and are of general interest for this reason.

In contrast to the other urban case studies, the Brussels case study uses a static framework that is limited to a single year, 2005. The effects of alternative policy designs are analysed relative to a given forecast traffic equilibrium for 2005. In the first part of the case study policy instruments are successively added to a policy package in order of perceived ease of implementation: first more efficient parking pricing, then improved public transport pricing, and finally an optimal

[8] Recall that this value refers to MCPF-1 when using the traditional definition of MCPF.

road cordon toll; see Table 6.2. Similar to the other case studies, each step is referred to as a "phase". But because there is no progression of calendar time the sequence of phases will be called an "implementation plan" as a reminder that it is a-temporal.

The Helsinki Case Study

The Ministry of Transport and Communication of Finland recently struck a committee to determine possible changes to transport charges and taxes. The base-case path specified in Table 6.3 is a (rough) description of the path suggested by the committee, adjusted to the Helsinki urban/metropolitan setting and the model used for the case study. There are three primary policy instruments: tax on fuel, public transport fares, and peak-period radial/cordon tolls. In the reference period (Phase 0, 2000-02) only the first two instruments are in place and they are set at approximately current values. In Phase 1 emphasis is placed on selected measures of effectiveness, and the instruments are adjusted only slightly while maintaining fiscal neutrality. In Phase 2 more weight is placed on welfare in the objective function and further adjustments are made, and peak-period radial/cordon tolls are introduced. Finally, in Phase 3 fixed transport charges and land prices are assumed to be adjustable too and the full set of policy instruments is set to achieve an approximate first-best optimum.

The Oslo Case Study

The implementation path for the Oslo case study (see Table 6.4) consists of four phases: Phase 0: 2002. Prices for 2002 are set at the actual levels for 2002. It is assumed that, due to technological and legal barriers, only second-best policy instruments are available for optimisation in Phase 1 from 2002 to 2015. These instruments include (1) toll charges, (2) public transport fares, (3) parking charges, (4) road capacity, and (5) fuel charges. To account for gradual change in transport behaviour and land-use changes over this period, linear interpolation is used to determine values of pricing instruments and welfare effects in intermediate years.

First-best road link charging becomes technologically and legally feasible in Phase 2 in 2015, and is used together with the second-best policy instruments until 2030. Values of instruments and welfare effects in intermediate years are determined by linear interpolation between 2015 and 2030. Phase 3 (2030) represents the long run impact of 15 years of marginal social cost pricing.

A general constrained optimisation algorithm and a land-use and transport model for Greater Oslo (RETRO) are used to determine the MCP levels of instruments and to forecast the short- and long-term welfare effects at the stages along the implementation path (i.e., it is possible to perform genuine second-best optimisation in each phase of the implementation path).

Table 6.1 Implementation paths for the Paris (Ile-de-France) case study

Phase	Coverage or scope of the pricing system	Composition and levels of pricing measures	Degree of differentiation of pricing measures	Rules and principles governing revenue use	Use of suppl. non-price measures
Phase 0 (2002)	Tolls limited to selected radial Autoroutes (A1+A6 and/or A4+A13) or a ring road (A86).	Flat tolls. Tolls set at low levels to reduce political opposition.	By link.	Marginal cost of public funds = 0.14. (Consistent with "Bureau du Plan".) Revenue allocation not accounted for other than for MCPF.	None.
Phase 1 (short term, 2005) .	Tolls imposed on all selected radial Autoroutes (A1+A6+A4+A13) and ring road (A86).	Flat tolls. Tolls set to maximise welfare.	By link.	As Phase 0.	None.
Phase 2 (medium term, 2008)	Cordon toll around Paris Centre. (No link tolls.)	Time-dependent tolls.	By time of day.	As Phase 0.	None.
Phase 3 (long term, 2012)	As in Phase 2, but with two cordon tolls around Paris Center and Boulevard Périphérique. A time tax on all auto travel.	As Phase 2 plus first-best approximate by time tax (raised by 50% or 100% of equivalent existing fuel price).	By cordon and by time of day.	As Phase 0.	None.

Table 6.2: Implementation plan for the Brussels case study

Phase	Coverage or scope of the pricing system	Composition and levels of pricing measures	Degree of differentiation of pricing measures	Rules and principles governing revenue use	Use of suppl. non-price measures
Phase 1a	Urban area. Parking pricing. All other policy instrument s remain unchanged.	Parking fees set at resource cost (to cover resource cost). Free parking is abolished.	No time or spatial differentiation of parking fees	Revenues are returned to all inhabitants & commuters, and MCPF=0	None
Phase 1b	Urban area. Public transport pricing. All other policy instrument s remain unchanged	Public transport prices optimised (in 2nd best sense).	Public bus fares differentiated over time	As Phase 1a	None
Phase 2	Urban area. Parking pricing + Public transport fares.	Parking fees as in Phase 1a. Public transport prices as in Phase 1b allowing for revised parking pricing.	Parking fees as Phase 1a + Public bus fares as Phase 1b.	As Phase 1a + No budget constraint on public transport	None
Phase 3	Urban area. Parking pricing + Public transport fares + Congestion pricing.	Parking fees as in Phase 1a. Public transport prices as in Phase 1b. Optimal space and time differentiated (electronic) congestion tolls.	As Phase 2 + ERP space and time differentiated	As Phase 2	None

Table 6.3: Implementation path for the Helsinki case study

Phase	Coverage or scope of the pricing system	Composition and level of pricing measures	Degree of differentiation of pricing measures	Revenue use	Use of supplementary non-price measures
Phase 0 (current situation, 2000-2002)	Whole study area. Fuel tax. Public transport fares. Fiscal fuel tax	Fuel tax and public transport fares set at approximately current values. Measures comply with all current acceptability & institutional barriers.	None/minimal differentiation.	Through the state budget. Marginal cost of public funds=0.	None.
Phase 1 (short term, 2005)	As in Phase 0. In addition, focus on demand management and environment.	Fuel tax & public transport fares adjusted slightly to enhance welfare. Fiscal revenues kept the same.	By mode and vehicle type.	As Phase 0.	None in base case. Variations consider either road or road & public transport investments.
Phase 2 (medium term, 2010)	As in Phase 1. Radial/cordon fixed road peak charges added.	Fuel tax & public transport fares adjusted further. More emphasis on social welfare. Fiscal revenues still kept the same.	By link/location, mode and time of day.	As Phase 0.	None in base case. Variations consider road, public transport, or road & public transport investments.
Phase 3 (long term, 2015, 2020)	All relevant benefits and costs considered.	Towards (practical) maximisation of social welfare.	By link/location, mode, and time of day.	As Phase 0.	As Phase 2.

Table 6.4: Implementation path for the Oslo case study

Phase	Coverage or scope of the pricing system	Composition and level of pricing measures	Degree of differentiation of pricing measures	Rules and principles governing revenue use	Use of supplementary non-price measures
Phase 0 (current situation, 2002)	Covers the whole of the study area: Greater Oslo Current measures: -Toll ring charges (finance of road and PT development) - Parking charges (fiscal purposes) - Fuel taxes (fiscal purposes) - Public transport fares.	Current levels.	None	Through the state budget (fuel charges) and the city budget (toll and parking charges and fares).	None
Phase 1 (2015)	As Phase 0.	Optimal pricing of car and public transport based on welfare optimisation with available pricing measures (unconstrained or constrained by upper and lower limits, equity impacts and city budgets). Second-best measures: -Peak toll ring charges -Public transport fares Parking charges fixed at current levels as in Phase 0. Fuel taxes either at current levels or with added CO_2 charge.	Per mode	Marginal cost of public funds (MCPF) = 0	Road and public transport investments (the same as those in do-min). Public transport frequency changes to make capacity according to demand.
Phase 2 (2015)[1]	As Phase 0 + Road link charges.	First-best measures: road link charges. Second-best measures: as Phase 1.	As Phase 1	As Phase 1	As Phase 1
Phase 3 (2030)[2]	As Phase 2	As Phase 2	As Phase 1	As Phase 1	As Phase 1

6.3 Case studies on modelling interurban road, rail and water transport

6.3.1 Case countries and models

For interurban transport four simulation-modelling case studies were carried out focusing on the Netherlands, the UK, the EU15 and Norway. The case studies concentrated heavily on freight transport, as being the priority problem, but also considered the interaction between freight and passenger charging, between modes of transport, and between charges and the rest of the economy, including via the use of revenue. In three of the case studies, large, existing, dynamic network models were used: SMILE for freight transport in the Netherlands, SCENES for freight and passenger transport covering all Europe and PINGO/NEMO for freight transport in Norway. In the fourth case study dealing with freight and passenger transport in the UK, a new, more aggregate, model was developed.

The way the case studies addressed issues relating to the different key dimensions of the pricing system is summarised in Table 6.5. The aim has been to make use of the specific strengths of the different simulation models while taking into account their inherent limitations.

Table 6.5: Focus of the modelling work in different case studies

Key dimensions	*KUL*	*SMILE*	*PINGO/NEMO*	*SCENES*
I. Coverage or scope of the pricing system	Road freight and passengers UK data	Freight via road, rail and IWW Netherlands	Freight via road, rail and sea Norway	Freight via road, rail, IWW and sea; passenger via car, coach, rail and air Europe
II. Composition and level	Optimal congestion charges	All externalities	All externalities	All externalities
III. Degree of differentiation	Between passenger and freight	Geographical differentiation	Geographical differentiation	Motorways and/or non-motorways, passenger and/or freight
IV. Revenue use	Labour tax or lump sum subsidies	Not modelled	Modelled endogenously as lump sum	Not modelled

6.3.2 Implementation paths

The three case studies in which the dynamic network models were used evaluated the following implementation paths defined in Niskanen et al (2003a):

1. “Do nothing” (or “Do min”)
2. “First best”
3. Phased implementation starting with heavy goods vehicles (hgvs)
4. “Only road pricing for freight transport”
5. “Only road pricing, all traffic”

Similarly to the urban modelling analyses, the implementation paths modelled were exogenous, rather than sequences of endogenously determined second-best optima. The first two alternatives were determined according to the same principles as in the urban transport cases. The third alternative is described in Table 6.6. The fourth and fifth alternatives are variations of the third one. The fifth one was only analysed with the SCENES model.

Table 6.6: Implementation path: "phased implementation starting with hgvs"

Phases ***Key dimensions & second-best constraints***	***Phase 1*** ***(short term, 2005/2006)***	***Phase 2*** ***(long term, 2015)***
Road	Kilometre charge for commercial traffic. Could be a simple charge per country; however, differentiated by environmental performance and by axle weight. Possible charges for accidents and noise. Higher charges on environmentally sensitive zones. Fuel taxes may be partly replaced by the new kilometre charges.	Full marginal social cost coverage. More differentiation regarding place of driving to reflect environmental costs, noise and congestion costs. Fuel tax only to cover CO2. NB: still only commercial traffic!
Rail	No changes (only infrastructure charges)	Introduce external costs, air pollution, and noise in the charges.
Water	Introduce differentiated charges by vessel type, on emissions and noise, but in a revenue neutral way.	Environmental costs, but no longer in a revenue neutral way. Climate change cost, either in fuel taxes or separate climate change charges.

6.4 Key results from modelling case studies on implementation paths

We will next present, in subsections 6.4.1-6.4.2, key conclusions from the modelling results under the following headings:

- Overall effects on welfare and other transport indicators (transport volumes, environment, etc)
- Detailed results (synthesis and comparison)

6.4.1 Overall effects on welfare and other transport indicators (transport volumes, environment)

6.4.1.1 Urban transport pricing

The main quantitative results of the four urban case studies are summarised in Table 6.7. It is evident that both the welfare gains per capita from pricing reform and the extra revenues generated vary considerably with stage of implementation for a given case study, and also differ significantly across case studies. In each case study except Brussels (which uses a static model) the welfare gains increase monotonically along the implementation path. For Paris, some form of pricing is assumed to be introduced in the base period/status quo, whereas for Helsinki and Oslo pricing reform does not begin until later.

Table 6.7: Comparison of main urban case study results

Case study	Period	Year	Population (10⁶)	Welfare gains (€/capita/yr)	Pricing revenue (€/capital/year)	Largest benefit component
Paris	Status quo	2002	3.4[2]	39	39	
	Short run	2005	3.6[2]	72	69	Route shift
	Medium run	2008	3.7[2]	91	89	Peak shift
	Long run	2012	4.0[2]	137	136	Modal shift
Brussels	Long run	2005	1 inhabitants + 0.7 commuters	172	207	Paid parking and peak shift
Helsinki	Status quo	2000	1.62			
	Short run	2005	1.72	141	81	Modal shift
	Medium run	2010	1.83	246	156	Modal shift
	Long run	2015/20	1.88	401/403 191 present value	244/353	Modal shift
Oslo	Status quo	2002	0.95			
	Short run	2015	1.1	50	55	Modal shift and relocation
	Medium run	2015+	1.1	222	1200	Modal shift and toll revenue
	Long run	2030	1.1	279	682	Modal shift and toll revenue

[1] Includes toll revenues & fuel taxes with VAT.

[2] The population figures for Paris refer to the number of commuters. and not the number of city inhabitants.

In Paris, annual per capita efficiency gain from pricing in the short-run (Phase 1), medium-run (Phase 2) and long-run (Phase 3) amounted to € 72, € 91 and € 137 respectively. In Brussels, when set optimally by a single level of government, the full set of instruments yielded appreciable annual welfare gains of € 172 per capita. In Helsinki, discounted to year 2005, the annual present-value per capita efficiency gain from the 'basic' path was € 191. Instantaneous implementation of the selected policy package (the "big bang") yielded a higher time profile of efficiency gains than did the 'basic' path, and a present-value per capita efficiency gain of € 227. (The big bang was however considered only as a theoretical benchmark, as it entails large and immediate changes in prices, which would be impractical or impossible on account of barriers.) In Oslo, annual per capita efficiency gain from pricing in the short-run, medium-run and long-run amounted to € 50, € 222 and € 279 respectively.

These results are sensitive to the characteristics of the study area and to the prices chosen for the base forecast. For Brussels, Helsinki and Oslo, the estimated welfare gains derive from packages of pricing instruments that support, at least approximately, a first-best pricing. The Helsinki and Oslo figures are closest in that they both feature a model with endogenous land use. For Paris the gains from first-best pricing are probably somewhat higher than reported above because, due to computation time constraints, it was not possible to optimise the location and time variation of tolls very precisely. In all studies except for Paris it was assumed that road pricing has not yet been implemented at the start of the analysis period. The gains from first-best pricing are therefore higher than they would be if some form of marginal-cost or efficiency-based priced were already in place, as is the case in London and Singapore.

Comparing these welfare gains obtained in the long-run scenarios it is striking that the smallest annual benefits per capita accrue in the largest city (Paris) and the second-highest gains in the smallest city (Oslo). Since congestion externalities at least are expected to increase with city size, this finding is somewhat counterintuitive. A number of reasons was however suggested (and discussed), including differences in the calendar date chosen for the long run (which varies from 2005 in Brussels to 2030 in Oslo), population density, land-use effects, road network effects, public transport ridership effects, numbers of trips per day, sets of pricing instruments and degrees of price differentiation, use of supplementary non-price measures, precision of the objective function optimisation procedure, and so on.

Particularly interesting and important is the role of the network effects and the joint influence of them and the nature of the model used. All case studies except Brussels included detailed transport networks. From the considerable transportation engineering and transportation economics literatures, it is well known that networks can behave in subtle and counterintuitive ways (e.g. the Braess paradox). Indeed, it is not obvious whether network effects act to increase or decrease the efficiency gains derived from marginal-cost based pricing.

Networks present travellers with an additional dimension of choice: choice of route. To the extent that this offers a greater scope for efficient response to pricing, one might expect the efficiency gains from pricing to be higher. However, greater scope for response may also allow travellers to *reduce* the impacts of charging or even make them counterproductive; in particular by switching from tolled to alternative untolled routes. This latter point was raised in the AFFORD project (Milne et al, 2000) which argued that strategic and geographic models — which lack detailed network representations — tend to yield higher estimated benefits for marginal-cost pricing than do detailed simulation and tactical models.

The upshot of this reasoning is that network models may yield higher benefits if pricing is relatively comprehensive, but lower benefits if it is not. This is consistent with the fact that the Brussels study (with its aggregate model) obtained lower benefits than did the Helsinki and Oslo studies with their detailed models in their final phases when pricing is comprehensive. To be sure, Paris also employed a detailed network model as well as a fully disaggregated trip-timing dimension, and the pricing was comprehensive in the final phase. But the time-based tax was crude in terms of its geographical variation, and cordon tolls were crude in terms of their time-dependence. The pricing scheme therefore fell a long way short of steering traveller behaviour in optimal directions, and this may contribute to the relatively low welfare gains obtained in the Paris study.

Figure 6.1 plots the gains over the course of the implementation path as a fraction of the gain achieved in the final phase or long run. (The Brussels results are excluded from the figure since no temporal implementation path was considered for this case.) The curves for Paris and Helsinki are similar in that the benefits grow in fairly equal increments from phase to phase. By contrast, for Oslo more than 3/5 of the benefits accrue in 2015+ when road link charges are deployed.

The shapes of “benefit growth” curves such as those in the figure are governed by numerous area-specific factors, and it is presumptuous to draw any general conclusions from the three curves shown. At best, one may take the results as representative of two possible trajectories. The trajectory exemplified by Paris and Helsinki is one of steady incremental gains with no single phase being decisive in capturing the bulk of the potential gains from reform.

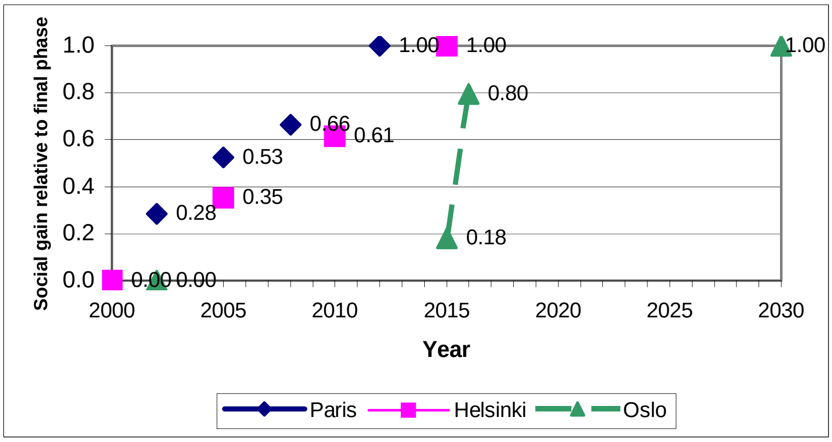

Figure 6.1: Efficiency gains relative to final implementation phase

Oslo typifies another trajectory in which one stage is dominant. In Oslo's case this is because road link charges turned out to be much more effective than other instruments. In other areas a similar trajectory might eventuate because barriers to implementation preclude major innovations in the first years of implementation, or because the authorities choose to proceed slowly with small demonstration projects in order to gain public acceptance. London's scheme is hardly "small" but the benefits of road pricing in London may nevertheless follow an Oslo-like trajectory.

The linear and logistic trajectories discussed here are but two possibilities out of many. Another possibility is a concave curve that might obtain if synergies between instruments are zero or negative, and if instruments are adopted in order of diminishing returns or decreasing priority. Whether a strategy of picking first the low-hanging fruit in terms of efficiency would also facilitate acceptability is another matter.

Efficiency gains derive from changes in behaviour. In all the urban case studies modal shifts were identified as the largest contributor in the long run. However, the relative importance of the dimensions of behaviour included in a model can change from phase to phase of an implementation path. In Paris, for example, route shifting is predominant in the short run when pricing is limited to flat tolls on selected links, peak shifting is predominant in the medium run when time-varying tolls are introduced on a cordon, and modal shifting is predominant in the long run when a time-based (fuel) tax is implemented.

6.4.1.2 Interurban transport pricing

The interurban modeling case studies (the Netherlands, Norway) showed that the impacts of marginal cost pricing are, broadly speaking, threefold. The impacts on total transport volumes and modal shares are minor (marginal); the impacts on consumer (household) welfare are negative; and the impacts on total social welfare are positive due to significant environmental benefits.

For the case study on interurban freight transport pricing in the Netherlands (SMILE model), in the "Do nothing" scenario i.e. without any policy changes, the total transport performance (measured in tkms) increased by 55% between the years 2000 and 2020. The transport performance of all modes grew, but the modal shares of inland waterway (IWW) and rail slightly increased at the expense of road transport (by 0.5% and 0.7% respectively). In absolute terms road transport accommodated most of the growth. Technological developments led to reduced environmental and safety cost per kilometre, but due to the increased demand for transport total externalities increased (especially marginal infrastructure cost).

The alternative pricing scenarios or implementation paths led to only a 0.2% to maximum 1% lower total transport volume in 2020 compared to the “Do nothing” scenario. The overall impact of transport pricing on transport volumes was thus concluded to be only marginal. Of course, this does not necessarily mean that also the welfare effects are marginal. These impacts are discussed below.

As for the induced shifts in modal shares road gained additional market share under all implementation paths. In part this was concluded to be due to the fact that charging the social marginal cost for all modes will result in relatively high increases of transport cost for rail and inland waterway. But the result was obtained also when only road freight was charged. This was explained by the fact that, according to the scenario assumptions regarding improved technology for road transport, externalities of road transport decrease faster than those of the other modes; this will result in lower charges for road transport under the MCP principle. Thirdly, geographical differentiation of charges makes some road transport links cheaper, namely those through less densely populated areas.

Along the implementation path “phased implementation starting with hgvs” there was a minor dip in the development of road transport volume in 2006, when the pricing regime for road transport changed. In 2016 when all modes were charged the full marginal cost, IWW and rail transport suffered a loss of modal share of 2.3% and 0.5% respectively. In case only road was charged (first road charging under marginal cost and around 2015 full marginal cost pricing for road), IWW and rail did not lose their market shares.

The case study on interurban freight transport in Norway (PINGO/NEMO model) demonstrated similar results. Figure 6.2 shows the total freight transport on road, railways and water in Norway (tkms) for the different implementation paths (from 2001 to 2006, then to 2012, and finally to 2022). The figure shows relatively small differences between the paths compared to the changes in the level of transport in general. The relatively small impacts of pricing was concluded to be in part due to the expected future economic growth and the fact that a great share of the externalities are already internalised along the do-min path as existing transport taxes.

Figure 6.3 shows the corresponding changes in modal shares between road freight and the non-roads modes (rail and water). These changes are very minor too.

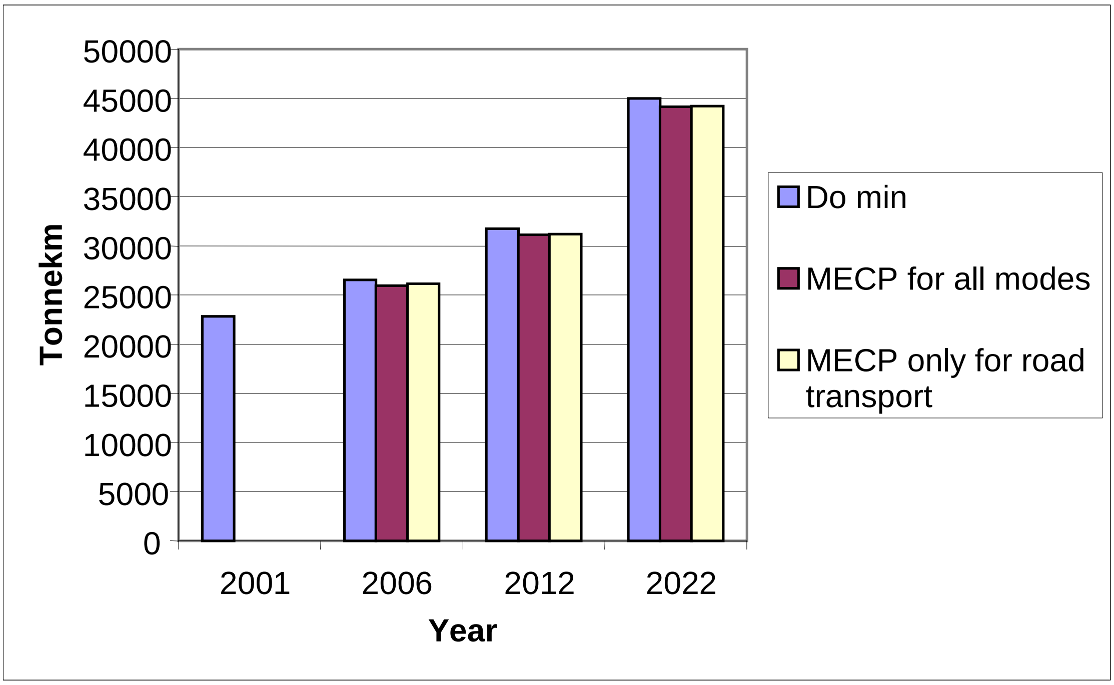

Figure 6.2: Total yearly tkms in Norway along the implementation paths

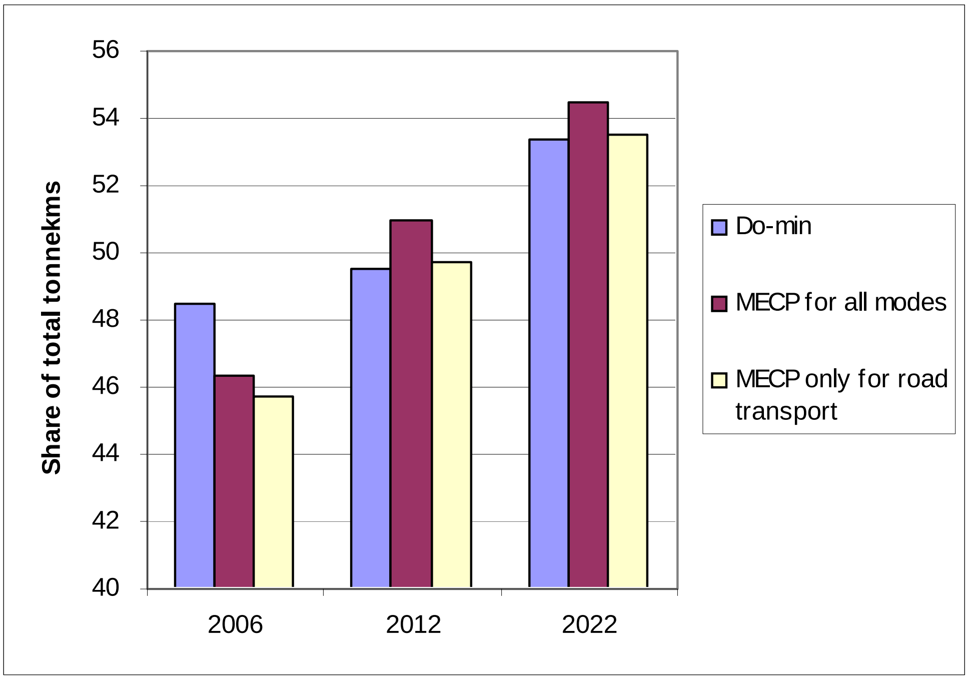

Figure 6.3: Share of total tkms by road along different implementation paths.

Similarly, the estimated welfare benefits did not appear that great either, in particular in comparison to corresponding indicators in other sectors (though the inclusion of environmental benefits can in many cases significantly boost these benefit numbers). In particular, in Norway the welfare effects (consumer surplus) without external cost reductions were negative for all variations of implementation paths analysed. Table 6.8 summarises the results.

Table 6.8: Welfare and its composition under two implementation paths relative to the do-min situation (million € per year)

	MECP for all modes			MECP only for road transport		
Year	**2006**	**2012**	**2022**	**2006**	**2012**	**2022**
Consumer surplus	-13	-18	-84	-6	-13	-24
External costs	66	56	179	60	66	189
Total	**53**	**38**	**95**	**54**	**53**	**165**
Revenue	679	750	1677	389	811	1427

Figure 6.4 illustrates the development of total welfare effect for the two implementation paths examined. It is somewhat counter-intuitive in that it seems to imply that marginal external cost pricing for road transport only yields higher social benefits than marginal external cost pricing for all modes. There are a number of possible reasons for this. Firstly the pricing reform proceeded by adding external cost to existing prices less taxes/charges for infrastructure use. This may lead to distortions in the prices of non-road modes which are subject to economies of scale. Secondly the PINGO model incorporates a fixed use of revenue in proportion to existing government spending. This severely non-optimal revenue use may mean that pricing for external costs is only worthwhile where substantial benefits accrue.

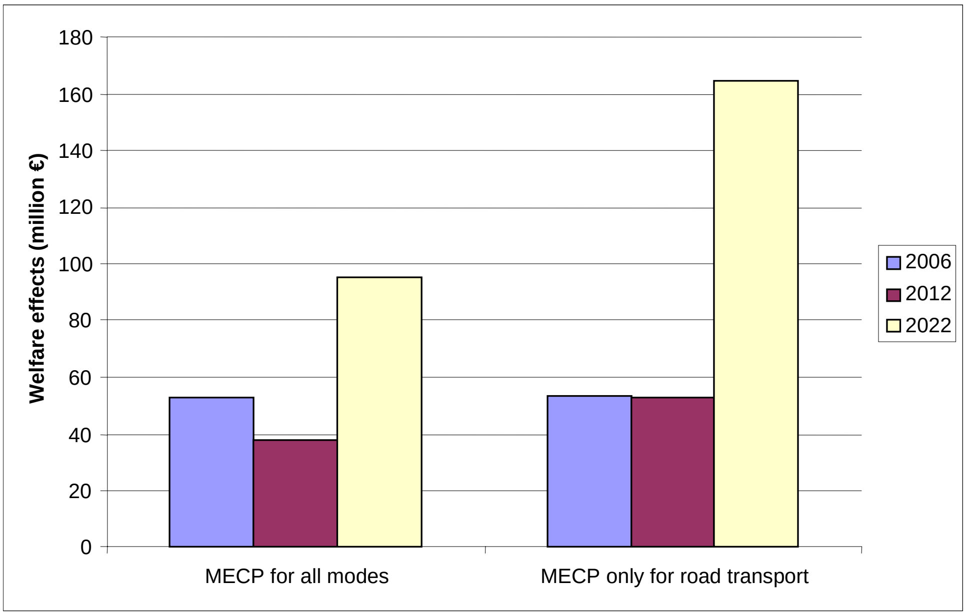

Figure 6.4: Development of total welfare measure along two implementation paths for Norway (million € per year).

6.5 Detailed results (synthesis and comparison)

This section provides a detailed description of the results of the MC-ICAM modelling case studies. We present the key results of the urban and interurban case studies in parallel in order to provide a comprehensive synthesis and comparison. We discuss, the results under the following headings (corresponding to the five key dimensions of pricing discussed earlier):

- Impacts of pricing system as a function of its scope
- Optimal prices in phased implementation
- Impacts of differentiation
- Impacts of the use of revenues
- Long-term impacts through land use

That is, the impacts of individual measures (and policy packages) will be looked at from different angles. From the viewpoint of scope: how comprehensive the measure is and what are the implications? From the viewpoint of optimal combinations and levels: are there e.g. synergies between different measures and what are the implications? From the viewpoint of differentiation: can the measure differentiate and what are the impacts? And so on.

6.5.1 Impacts of pricing system as a function of its scope

Both the urban and interurban case studies provided estimated welfare effects and other indicators as a function of varying scope/coverage (routes or areas covered geographically, modes covered, etc) of the pricing system. The key conclusions include the following:

- In Paris link tolls did not bring much benefit, because only a very small portion of the road network in Ile-de-France was tolled, and therefore tolls needed to be set very low in order to avoid undesirable diversion of traffic to untolled alternative routes. The welfare gains from tolling several routes were approximately additive; i.e. equal to the sum of the gains from tolling them independently. This result was attributable to the fact that the tolled infrastructure was well separated geographically so that traffic spillover effects between tolled routes were minimal.
- In Paris, both the cordon tolls in Phases 2 and 3 and the time tax in Phase 3 yielded considerably higher efficiency gains than did the link-based tolls in Phases 0 and 1. The link-based tolls were limited in their effectiveness simply because the scope of link-based tolling was itself limited. However, if the link tolls were extended to a sufficiently large portion of the road network, they would ultimately surpass both cordons and the time tax in effectiveness because they can be varied more finely with respect to location and time of day.
- In Brussels, appropriate pricing of parking alone produced more than one third of the benefits of the optimum.
- In Helsinki policy measures with restricted geographical coverage (e.g. a cordon toll or reduced PT prices in the metropolitan area only) yield reduced welfare gains. The welfare sacrifice is proportionally smaller in the early phases of implementation than in the later phases due to the fact that the region is growing and urban sprawl will furthermore locate more population outside the metropolitan area, which will increasingly create externalities there.
- In the Netherlands, optimal pricing of road freight alone (including congestion externality and environmental externalities) gave 50% of the benefits of optimal pricing of all freight modes (road, rail and inland waterways).
- In Norway the positive welfare effect of pricing road freight only for external costs actually appeared to exceed those of charging all modes. Possible reasons for this counter-intuitive

result were given above, but it would certainly appear likely from this result that appropriate charging of road freight is the top priority.

6.5.2 Optimal prices in phased implementation

The case studies investigated issues related to synergy (substitutability, complementarity) between different pricing instruments. They illustrated the possibility of regret: second-best pricing along an implementation path can lead to big fluctuations in transport prices and even reversals in the direction of movement of charges. One case study (of Brussels) addressed impacts of different charging instruments being determined by different levels of government. And another two studies investigated how an optimal price can depend on the way revenues are used. The key conclusions include the following:

- In Brussels, parking fees and public transport fares displayed diseconomies of scope: the total welfare gain from implementing them jointly was less than the sum of the welfare gains from applying them independently.
- In Brussels, levels of prices increased or decreased when more control instruments were added. For example, in the short term, the best policy for public transport in the absence of road pricing was to reduce peak fares, whilst when full marginal social cost pricing was introduced on roads peak public transport fares needed to be greatly increased. (However, the initial reduction in public transport fares achieved only a small part of the benefits of road pricing.)
- In Oslo, over the course of an implementation path, relevant prices first increased and then decreased. Correspondingly, the welfare impacts (in term of consumer surplus) of progressive marginal-cost pricing changed not only in magnitude but also in sign. The reason for this was inertia in relocation and other behavioural adjustments. For example, in the implementation path without restrictions either on the use of policy instruments or a supplementary fuel tax, auto and public transport users together gained in the short run, were made significantly worse off in the medium run when link-based charges were introduced, but recovered partly in the long run when they became able to relocate.
- In the UK the optimal price for road freight was higher if freight alone was charged (here a congestion charge) but passenger transport was not. This could lead to problems later, if also passenger transport pricing is introduced implying a need for a reduction in the price for freight transport.
- In Brussels, while it appeared to be best in principle for decisions on cordon pricing and parking charges (also for the use of revenues) to be concentrated at the regional level, the city to have control of parking charges (and to share the revenue) was not too damaging. What would be damaging is if the city had control of the cordon charge, which would have its biggest impact on those living outside the city. Overall, the results of the case study suggested that practical compromise solutions can be found.
- In Brussels, an efficiency loss occurred because the city government overcharges for parking in order to export taxes to commuters that are outside its jurisdiction. The regional government responds by setting a cordon toll that is lower than the first-best optimal level in order to avoid discouraging commuting too much. Despite the tensions between the two levels of government, the non-cooperative Nash and Stackelberg equilibria considered achieved most of the welfare improvements that obtain in the fully coordinated centralised solution. This finding was a result of two assumptions: both governments are welfare- rather than revenue maximisers, and the constituencies of the two governments overlap so that their interests are partially aligned.
- In Oslo optimal peak toll charges were relatively small after long term use of link-based road link charges, which confirmed that the link based toll charges internalise much of the external costs on the links that are not internalised by fuel charges. (Fuel charges and link-

based tolls were substitute measures for alleviating congestion.) The optimal peak toll charges were slightly lower in scenarios with an extra fuel tax that already internalises some of the external cost, and makes less need for toll charges to internalise remaining external costs.

- In Helsinki policy packaging was useful, as the instruments were clearly complementary to each other for example by evening out large variations in the cost components of the welfare analysis (increasing acceptability). For example, reduction of public transport fares combined with an increase of petrol tax reduced the (overall) losses in users benefits and decreased the government benefits while the savings in externalities grow. However, the combination seemed to be less efficient than the sum of the individual measures as the effectiveness of the measures "overlap" with each other which suggests that the policy conclusions has to be based on the packaged approach also in the analysis rather than combining individual studies.
- In the UK, the optimal charges for interurban road depended on the way the revenues are used: optimal charges are higher where revenues are used in best way. Indeed, this appeared to have a dominant impact on the optimal price level. Evidently in this way the indirect benefits can be made even larger.
- In Norway, similarly, the optimal price depended on the way the revenues are used.

6.5.3 Impacts of differentiation

The urban case studies showed considerable social benefits from differentiation of prices over time (peak and off-peak). The interurban case studies showed that geographic differentiation can have remarkable social benefits and significant impacts on modal shares. But the studies also showed that differentiation can benefit those (here road freight) who are the object of pricing. The key conclusions include the following:

- In Paris time-differentiated tolling yielded greater efficiency gains than did flat tolling. However, the implementation path did not illustrate the full potential of modular pricing for two reasons: first because time variation was limited throughout to a single time step (*i.e.* to a peak/off-peak differential) and second because the time variation was not optimised independently for each component of the tolled infrastructure. The comparison of flat and differential tolls showed that inclusion of more time steps can boost welfare gains appreciably.
- In Brussels, greater efficiency gains derived from measures that are differentiated according to the circumstances of usage. For example, when public transport fares were differentiated between peak and off-peak periods, and road tolls were differentiated by space and time boosted gains appreciably.
- In Helsinki while differentiation of prices increased total welfare, the long-term study areawide impacts e.g. the lengthening of average distance of trips can also drive the overall levels of prices. For example, total distance travelled has a spatially undifferentiated effect on many welfare assessment components. This also depends on the price levels assumed (determined by the authorities) in the base forecast. Therefore, a high level of petrol price may have positive impacts (according to the assessment framework usually used for infrastructure investment analysis). However, a fuel tax is advantageous as a policy instrument inasmuch as it applies areawide and, unlike a cordon toll, does not induce undesirable route diversion. But for congestion pricing the fuel tax is a blunt instrument both spatially (it does not discriminate between routes) and temporally (it does not discriminate between peak and off-peak periods). Also, the feasibility of implementing a higher fuel tax in an urban area than outside is highly debatable.
- In Oslo, similarly, increased differentiation along the implementation paths increased the overall welfare.

- In the Netherlands, the welfare effects from charging road freight increased almost linearly with increased geographical differentiation of charges (i.e. the later steps in differentiation yielded only slightly smaller additional benefits than the first steps). In the Netherlands and Norway, when full geographical differentiation as part of social marginal cost pricing of road freight was introduced, the share of road transport was higher than in the do-nothing alternative. This appeared to be true even when only roads were charged. In part this was interpreted to be due to the fact that geographical differentiation makes road transport links through less densely populated areas cheaper. (Partly the result was due to adopted scenario assumptions concerning technological development and its impact on environmental externalities.) In case only road is charged, an increased geographical differentiation might lead to an increased growth of road transport.

6.5.4 Impacts of the use of revenues

Both the urban and interurban case studies considered revenue use as an endogenous choice:

- In Brussels, when addressing institutional problems relating to different levels of government, while it appeared to be best in principle for decisions on pricing (cordon pricing, parking charges) and the use of revenue all to be concentrated at the regional level, it also appeared that for the city to have control of parking charges and to share the revenue is not too damaging. What would be damaging is if the city had control of the cordon charge, which would have its biggest impact on those living outside the city. Overall, the results suggested that practical compromise solutions can be found.
- In Brussels, the efficiency loss that results from the (partial) conflict between governments could be alleviated by changing the sharing rules for tax revenue in favour of the city inhabitants, although this comes at a cost of greater inequity to commuters.
- In Helsinki the use of revenues by ear-marking them for infrastructure development has been stated as a strong prerequisite by the local (transport) authorities for the use of new pricing measures like congestion charging. However, the model results showed that investing in additional transport capacity in an attempt to boost acceptability is justified economically only if there is sufficient demand to make use of the added capacity. Because the pricing measures induced a modal shift from driving to public transport, transit capacity investments tended to be more effective than road investments.
- In the UK the overall welfare benefits of freight transport charges were several times greater when revenues were used in the public sector (thus allowing for corresponding reductions in distorting labour taxes) than when they were returned to consumers or users as lump sum payments. In the latter case the welfare gain was only 20 to 30% of the welfare gain in the former case.
- In Norway, similar results were obtained.

6.5.5 Long-term impacts through land use

The modelling case studies focused on alternative pricing scenarios (policies) and on the impacts of alternative uses of revenues. They did not much consider the impacts of alternative policy packages in which non-pricing policies, such as investments, regulation, information provision etc, would be included as supplementary measures. However, two case studies investigated long-term (and indirect) impacts on traffic flows and welfare through land use and location decisions by households and industry:

- In Oslo the direction of land use effects clearly depended on which measures were applied for road pricing. A long-term effect of toll ring charges was that people and work places move away from the toll ring, both towards the city centre and towards more remote districts. By contrast, link-based charges had the long-term effect that people and workplaces tended to move back to the city. The long-term effects of a strategy indirectly but significantly affected many overall transport (and environmental) indicators through relocations of residences and work places to reduce travel costs. In general, transport policy measures can bring about changes in location decisions that affect many transport and environmental indicators, thereby highlighting the importance of accounting for land use changes in policy analysis.

- In Helsinki the direction of the land-use impacts follows also these patterns. The firms tend to decentralise when the price of travel goes up whereas households centralise. This way the average trip distances and therefore the impact of pricing on travellers is reduced. Toll cordons tend to concentrate interactions within borders and cause significant fluctuations in land values whereas distance-based systems do not have this effect, as the tolls cannot be avoided by land use relocation. The results of relocation effects between larger conurbations showed however that strong changes in transport pricing can alter the balance of population and employment of urban regions significantly which becomes an issue of competition between regions.
- In Helsinki it was concluded also that due to rigidity in land use (and transport) infrastructure, and inertia in location choices, implementation paths in the MEPLAN modelling framework exhibit hysteresis. This became evident when an abandonment of the basic path at an intermediate step resulted in a slight welfare loss relative to doing nothing. These results demonstrate the importance of accounting for land use changes when designing implementation paths for marginal social cost pricing.

6.5.6 Limitations of the Analysis

Several limitations of the methodologies used in the case studies were noted. First, those studies with detailed transport networks were constrained in how accurately fully optimal solutions can be found with reasonable effort. A second limitation was that none of the studies included estimates of the infrastructure and operating costs of pricing systems, or the adjustment costs incurred by agents when making policy-induced changes in location, auto ownership or other choices. Third, none of the case studies incorporated all relevant dimensions. The MC-ICAM urban case studies (and also earlier urban studies such as AFFORD and TRENEN) revealed the importance of including all relevant dimensions of behaviour when measuring welfare effects of policy reform; e.g. trip-timing (Paris), parking (Brussels) and location and land-use effects (Helsinki, Oslo). To be sure, building an all-inclusive model would take a huge effort and might result in an unwieldy tool that is very demanding of input data. Still, since potentially important dimensions of behaviour were excluded from the model analyses, questions inevitably arise regarding the magnitude, and even the direction, of the “omitted variable” bias.

Fourth, while several dimensions of user heterogeneity were featured in the (urban) case studies (e.g. heterogeneity in origin/destination, auto ownership, value of travel time, mode choice preferences, some studies also did evaluate the equity effects of policies according to location), none included differences in income explicitly, and none investigated the welfare-distributional effects of pricing by household socio-economic status or the effects of varying the welfare weights attached to different socio-economic groups.

6.6 Conclusions for practical implementation paths

In this chapter we present our conclusions for practical implementation paths. Our conclusions and recommendations are based on the results of our studies on barriers and constraints and of our modelling case studies. And of course they also more or less directly reflect our theoretical and methodological considerations.

We necessarily focus on aspects that are common to different localities. At the end of the chapter we will present some specific comments and recommendations regarding individual cities, countries and parts of Europe, that is, consider possible implementation paths for individual cities, countries, transport corridors or parts of Europe. (Individual case studies of course already provided valuable insights for their respective cities and countries.)

Adler et al (2003) stated that currently rail, air and water transport are at different stages of MCP implementation. Rail would appear to be the most advanced in this respect. MC-ICAM four case studies, which in detail specified the current pricing schemes in the United Kingdom, Germany and Sweden, and a slightly less advanced scheme in Hungary. In this historical analysis, it became clear that frequently watered-down versions of MCP schemes have been implemented, due to political, legal, market structure and acceptability barriers. All these three modes have the characteristic that access to them is controlled to ensure that capacity is not exceeded by demand, with the result that the inability to get the slot desired may be a cost imposed on other users. This is not explicitly allowed for in current infrastructure pricing in these modes.

Yet the biggest gains from pricing reform are likely to come from pricing urban roads. For urban transport, for instance, as reported above, the following welfare gains from optimal (first-best) pricing relative to the status quo were demonstrated (annual welfare gains per capita in the long-run scenarios of the case studies): € 137 for Paris, € 172 for Brussels, € 401 for Helsinki, € 279 for Oslo.

In order to discuss the whole range of policy issues that relate to the properties of the implementation path itself and to develop our conclusions concerning the most likely (and desirable) progress in implementing marginal cost-based pricing policies, we first consider the different dimensions that in our view best characterize the pricing system and that have been discussed above. As discussed earlier, the five key dimensions and the key policy questions, which are concerned with the progress in the dimensions, are:

Coverage or scope of the pricing system: Perhaps a natural first question regarding the non-technical (economic, social) aspects of the pricing system concerns its scope or coverage: What should be priced and who should pay? The answers here in part depend on constraints regarding the number of market segments that can be priced distinctly e.g. by: geographical or spatial coverage, modal coverage, user groups covered and externalities covered. An important question related to these issues is about priority: in what order? Evidently, the answer is partly affected by potential existence of synergy benefits.

Composition of pricing measures and their levels: A second key question concerns the optimal prices themselves: What should be the level and composition (i.e. which pricing instruments to use) of prices? Here, allowance may need to be made for maximum tolls or price caps, budget constraints determining minimum or maximum total revenues etc, and also possible distortions in other links, modes, regions and sectors.

Degree of differentiation: A third key question concerns the degree of differentiation – across vehicles / infrastructure users, over time and spatially. This in particular should be a key issue when considering pricing schemes in the longer run. The desired extent of differentiation depends on the additional welfare benefits associated with the further stages as compared to the costs of implementing a more sophisticated pricing system.

Use of revenues: It has long been argued by both researchers and policymakers that the use of revenues is a crucial issue for transport pricing. It has been argued, and also shown in various studies, that the way revenues are used can have great welfare impacts – often much greater than the direct impacts of pricing. And it is demonstrated in many occasions to be a critical question from the acceptability viewpoint (public and political).

Supplementary measures and actions: MC-ICAM has emphasised that the implementation of marginal cost pricing should be considered within broader policy packages including use of revenues and other supplementary non-price measures. Potential supplementary/supporting measures here include investments to increase capacity, non-price regulation in various forms, and information provision systems. They may also refer to other related policies like land use policies. Other types of policies that may be relevant to consider are related to institutional reform with the aim to remove or lower legal and institutional barriers. But similarly we can include/consider here also policies or actions that aim (directly) to promote technological development, and improve other practical preconditions (enablers) such as estimates of pricing relevant marginal costs and other relevant data.

The discussion in subsequent subsections on these issues is organised under the following headings:

- Technology
- Scope of the pricing system
- Combinations of pricing measures and their levels
- Degree of differentiation
- Use of revenues
- Supplementary measures and actions

That is, we present technology as a sixth dimension (and shortly address it first).

Tables 6.9-6.11 provide more detail. Table 6.9 covers urban and interurban road transport, table 6.10 gives a more detailed description of plausible phasing in urban transport, and table 6.11 summarises similar conclusions regarding rail, air and water transport modes while also including appropriate steps for interurban road.

6.6.1 Technology

The MC-ICAM studies on barriers and constraints concluded that technological issues (barriers) have never been a big issue in non-roads modes (rail, air and water). They have been a much bigger issue in road transport, both urban and interurban. In particular, the lack (or cost) of necessary technology or standardisation for interurban roads was identified as an important barrier. Therefore, the following focuses on urban and interurban road only.

Short term: In the short term, for purely technological reasons – but also for acceptability reasons – simple technologies will most likely be applied in urban road. However, there already are sophisticated applications of smart card technology for urban public transport and electronic road pricing (ERP) or electronic fee collection (EFC) for interurban road transport on specific links.

Medium term: In the medium term, ERP, possibly GPS-based, is extended also to urban roads. For interurban roads a top priority in the short run is European wide standardisation (harmonisation) of ERP (EFC) technologies.

Long term: In the long term, we believe, there will be full scale applications of ERP for urban and interurban roads and with smart card technology for public transport fares and parking charging technology integrated with the road charging system.

To minimize overall implementation costs along an implementation path, it may of course be desirable to use – even in the short run – charging technologies that lend themselves for further refinement and scope expansion in the longer run. MC-ICAM has, however, not addressed charging technologies in any great detail.

6.6.2 Scope of the pricing system

Key questions regarding the scope or coverage of the pricing system are: What should be priced and who should pay? The answers here in part depend on constraints on the number of market segments that can be priced distinctly e.g. by: geographical or spatial coverage, modal coverage, user groups covered and externalities covered.

Based on the results of the MC-ICAM studies on barriers and constraints we can conclude that:

In many urban areas, only parking pricing may be feasible in the (very) short term. However, private parking may need to be left outside the pricing scheme in the short term, although is likely to be included in the medium and long term. In some cases urban road pricing may be possible to apply to central urban areas and weekdays in the short term, but can only gradually be extended to cover all urban links and at all times in the medium and long term. Interurban road pricing may only allow for infrastructure damage in the short term but can be extended to comprise also environmental damages in the medium and long term. In the intermodal context, while road freight may be charged first in the short term, pricing may be extended to rail and water modes only later on in the medium and long term.

The urban modelling case studies concluded that if the scope of a pricing scheme is too narrow, its impacts can not be too encouraging. However, given that sufficient scope is secured, even relatively simple price structures, which indeed may be the only way to get started anyway, may generate significant welfare benefits. They may generate a relatively large proportion of the benefits achievable in the first-best benchmark. These kinds of conclusions provide reassurance that it really is worth opting for a phased reform of transport pricing, introducing simple measures and with restricted scope as soon as possible, rather than waiting until it is possible to introduce the ideal solution. Such systems may be a good starting point as e.g. the recent experience in London shows. The interurban modelling case studies concluded that, from a welfare perspective, pricing road freight can be a sensible first step in an implementation path. Marginal cost pricing for only road freight yielded a considerable welfare effect – up to 50-90 % of the benefits when all freight modes (road, rail and water) were charged.

Therefore, while our considerations on barriers and constraints suggest that the barriers/constraints to broadening the scope can be quite restrictive in the short term, the modelling case studies demonstrate that the scope does not need to be comprehensive if only it is ‘sufficiently’ broad. That is, in the beginning (especially) the scope of the pricing system can be relatively limited, and still the pricing may be worth introducing. The pricing system can only gradually be extended to cover more and more aspects in the medium and long term.

6.6.3 Combinations of pricing measures and their levels

A second important question concerns which pricing instruments to use and at what levels should the charges be set. Here, allowance may need to be made for maximum tolls or price caps, budget constraints determining minimum or maximum total revenues etc, and also possible distortions in other links, modes, regions and sectors (that is, the scope of the pricing system may also matter here). Also, in principle, the optimal level of prices may be influenced by the way the revenues are used. Furthermore, the choice of the pricing instruments and their levels may be affected by complications arising when different levels of government control different charges (and most likely the corresponding revenues too). Indeed, as discussed in Rouwendal et al (2002), the issues affecting the choice of instruments and their levels can be very complicated.

Economists' second-best analyses to allow for relevant constraints and institutional arrangements have typically been carried out in a static framework or model (Rouwendal et al (2002)). Therefore, an important question is how the results of the static second-best analyses and resulting policy conclusions translate to practice which is dynamic (evolutionary) and where the relevant equilibria under consideration may not be long lasting (if indeed they exist at all). For instance, there is the question about regret: the possibility that second-best optimisation at an earlier stage can lead to price levels that need to be radically changed – increased or decreased – later on when second-best constraints have changed (typically relaxed). Regret is also possible if tolling is implemented in a particular way (very simple, though with high sunk implementation costs), or on part of the infrastructure, only to be replaced later by tolling in other forms (sophisticated) or elsewhere.

For urban roads, whilst area-based charges and cordon tolls may be realistic in the short term, they could be replaced by distance-based charges in the medium and long term. Charges may need to be relatively low in the beginning (e.g. to allow for acceptability problems) but could move towards pricing relevant marginal costs in the medium and long term. One is that tax increases may evoke resistance similar to tax introduction, in which case it may be wiser to set taxes higher initially to avoid a second round of acceptability problems. Another is that early-stage welfare benefits may be important to maintain or gain support for transport pricing, which requires taxes to be set near their second-best optimal values early on. Public transport fare structures may need to be adjusted according to second-best principles in the short term, to allow for non-optimal (i.e. under-) pricing of private car, but could (and should) be adjusted towards relevant marginal costs (while allowing for equity constraints) in the medium and long term when distance-based charges for private car will be phased-in and approach pricing relevant marginal costs. As for interurban roads, whilst distance-based kilometre charges for heavy good vehicles (HGVs) will most likely be introduced in the short term, they may in some cases need to be compensated (revenue neutrality) by reductions in fuel and/or vehicle taxes (to gain sufficient acceptability).

As said, the MC-ICAM modelling case studies did not optimise the combinations of pricing instruments to be used at the different stages of the implementation path. They took such instruments more or less as exogenously given, in most cases even their levels, and at best (in some cases) focused on optimising their levels. They presented results showing whether certain pairs of instruments can exploit synergy benefits i.e. are substitutes or complements.

The case studies also showed how optimal price levels may depend on the way the revenues are used: the more 'optimal' the use of revenues is (i.e. the less constraints there are on this) the higher are the optimal prices (this is in order to reap indirect benefits).

These kinds of considerations are very relevant because, evidently in the short term, limitations on the types and combinations of charges and taxes used, maximum tolls or price caps, minimum or maximum total revenues, budget constraints, etc, can be strongly restrictive. Similarly there may be constraints in the use of revenues. But such constraints most likely should be able to be relaxed (partly due to new technologies available) in the medium and long term.

The modelling case studies also presented results that highlight the possibility of regret.

One case study (that for Brussels) showed that, in urban transport, public transport fares should first be lowered from the current level to allow for non-existing road pricing, but should later on be increased again after road pricing is introduced. Such a reversal of public transport fares policy could certainly cause problems in terms of acceptability, and indeed also could lead to harmful ‘lock-in’ decisions on home and job locations if the public does not correctly perceive and understand the policy. It will be necessary to consider carefully in the light of the achievable timescales for full road pricing whether the initial reduction in public transport fares is a sensible policy, although in terms of what had actually been modelled it is on the optimal implementation path.

Another case study (the UK interurban one) confirmed a similar result for road freight in an interurban context. It showed that if, initially, only road freight can be charged (the case study considered a congestion charge) but passenger transport cannot, the optimal charge for road freight is relatively high. However, later on when also passenger transport can be charged, the road freight charges should be lowered radically. Again, this does not appear to be an attractive (or realistic) policy recommendation for policymakers and the industry to accept. This finding may have relevant policy implications for a stepwise introduction of congestion pricing on both passenger and freight transport. If taxing passengers becomes acceptable later on and the authorities decide to increase passenger transport taxes, then from a welfare viewpoint it may be desirable to accompany this tax with a simultaneous reduction in freight transport taxes. In this case, the optimal implementation path appears to involve a large increase in road freight vehicle charges followed by a reduction.

A third study (Oslo) also showed that prices first increased and then decreased. Over the course of an implementation path the welfare impacts of progressive marginal-cost pricing changed not only in magnitude but also in sign. The reason for this is inertia in relocation and other behavioural adjustments.

These results highlight the need to be aware of the risks involved in proposing second-best solutions in a dynamic context. Second-best optimisation that allows for prevailing distortions (in other modes, markets etc) can lead (if taken too literally) to problematic policy implications from the viewpoint of longer-run development. In particular, such policy implications may lead to acceptability and credibility problems.

An obvious benefit of considering second-best optima along an implementation path – in the way done in MC-ICAM – is to provide a framework for identifying such potential problems. This also suggests an important lesson: Rather than focusing on fine-tuning of the derivation of second-best prices, and often very detailed technical problems related to implementation, the policymakers and analysts should pay more attention to careful identification and understanding of key barriers and their implied constraints, and the possibilities for removing or avoiding these.

6.6.4 Degree of differentiation

An important conclusion stated above was that, if sufficient scope of the pricing system is secured, even relatively simple price structures may generate significant welfare benefits. The degree of differentiation – across vehicles / infrastructure users, over time and spatially –

however should be a key policy issue when considering pricing schemes in the longer run. The desired extent of differentiation depends on the additional welfare benefits associated with the further stages as compared to the costs of implementing a more sophisticated pricing system. The question of longer-run benefits of differentiation and of more sophisticated pricing schemes is particularly relevant because future developments of the technology most likely will make differentiation in (almost) all relevant respects technically feasible, and, furthermore, in many cases also in a way that most likely will prove to be acceptable. One reason for this optimistic view is that, besides improving efficiency, differentiation may in many cases be a means to promote equity and acceptability too.

The MC-ICAM studies on barriers and constraints suggest that:

Evidently in the short term, flat charges in regard to most of the relevant dimensions (i.e. across users, over time and spatially) may typically be needed for technological or practical and acceptability reasons, but in some cases this may be because of legal/institutional reasons, e.g. required by fiscal laws. However, more differentiation in all relevant dimensions should be possible in the medium and long term. For urban road pricing, initially, ERP may need to be introduced anonymously i.e. with the same prices charged for all vehicles. However, the levels of charges should gradually move towards pricing relevant marginal social costs. And in the long term full distance-based pricing could (and should) be implemented with charges differentiated according to full marginal social cost and on all urban links and at all times. In urban parking charging, although publicly controlled parking fees can (and will) vary by location and time already in the short term, they should be further differentiated by location and time in the medium term and, ultimately, in the long term, they should be fully disaggregated to reflect implied costs (marginal and fixed) by location and time.

As for interurban road pricing, the kilometre-based charges may need to show no differentiation within country by time or space in the short term, but appropriate differentiation (to reflect induced costs) should be possible to introduce in the medium and long term. The geographic or spatial differentiation, however, may easily generate unexpected (and undesired?) impacts on modal share (as demonstrated by the case studies), and evidently should be introduced with care. Anyway, ultimately in the long term, the overall goal should be to set full GPS-based ERP according to full marginal social cost-based differentiation.

The MC-ICAM modelling case studies showed remarkable welfare impacts of increased differentiation, for both urban and interurban transport pricing. For urban transport, the focus was on differentiation over time. For interurban roads and in particular for pricing road freight there, the case studies (the Netherlands, Norway) showed interesting results regarding geographic or spatial differentiation. They for instance showed that, besides significant welfare impacts, increased geographical differentiation may affect modal shares (in favour of road freight!), may benefit those who are the object of pricing (i.e. road freight), and hence may improve acceptability. The results also showed that the welfare impacts of further geographic differentiation increased almost linearly with the degree of differentiation. For phasing of pricing measures, this suggests that every step towards further differentiation will create welfare gains, which in turn suggests that in the long run full differentiation should be a serious practical goal.

6.6.5 Use of revenues

It has been long argued by researchers and policymakers that the use of revenues is a crucial issue for transport pricing. It has been shown in various studies, that the way revenues are used can have great welfare impacts – often much greater than the direct impacts of pricing. And it is demonstrated in many occasions to be a critical question from the acceptability viewpoint (public and political).

But issues related to the use of revenues also arise in those practical situations where different levels (or different government agencies like neighbouring communities on the same level) of government are responsible for introducing different pricing measures, and possibly are allowed to retain the proceeds and to decide on how to use them.

The MC-ICAM studies on barriers and constraints concluded that earmarking may be a critical condition, to allow for acceptability and funding problems in the short term. However, in the medium and long term it may be have to be made less important because earmarking may create unwarranted constraints on policy options. Other than this, it is not easy to sketch clear (plausible, likely and general) trends regarding the use of revenue – contrary to the other dimensions (scope/coverage, composition/level, degree of differentiation) above. This is partly because the use of revenues as a policy issue evidently is often considered to be a (much) more political issue than the directly pricing-relevant issues just mentioned, with a perceived stronger economic content. It often also depends on the prevailing institutional setting, which may greatly vary between locations.

The modelling case studies demonstrated how the way revenues are used may have great impact on the calculated benefits of pricing. This reinforces the general idea that if earmarking occurs initially for acceptability reasons, it may be attractive to gradually abandon such practice. The 'best' way of using revenues may change over time, and it therefore appears attractive to maintain a longer-run flexibility in the allocation of revenues from transport pricing.

6.6.6 Supplementary measures and actions

MC-ICAM has emphasised that the implementation of marginal cost pricing should be considered within broader policy packages including use of revenues and also other supplementary non-price measures (or policies). Potential supplementary measures here include investments to increase capacity, non-price regulation in various forms, and information provision systems. They may also refer to other related policies like land use policies. Other types of policies that may be relevant to consider are related to institutional reform with the aim to remove or lower legal and institutional barriers.

But similarly we can consider here also policies or actions that aim to (directly) promote technological development, improve other practical preconditions (enablers) such estimates of pricing relevant marginal costs and other relevant data.

An important factor influencing the possibilities for implementing marginal cost pricing in general and also the choices of individual pricing instruments (their levels, degree of differentiation) of course is the availability of credible estimates and valuations of relevant marginal and other costs (as well as of some other key impacts or aspects). The lack of such credible estimates can be an important barrier to implementation.

In particular, in relation to rail, air and water modes, it was stated (Adler et al, 2003) that currently the lack of data on externalities like wear and tear, congestion and delays, scarcity, accidents and noise and air pollution leads to problems of computation of optimal or second-best optimal MC prices. However, the biggest problem of all was concluded to be dealing with scarcity. Therefore, it was concluded, a first or short-run step required should be to develop better estimates of scarcity and other externalities.

Rouwendal et al (2002) explored some of the complications for transport pricing that arise when either privatized (air-)ports or the operators using these have significant (spatial) market power. As this is likely to result in prices exceeding marginal private costs, second-best transport taxes may have to be set below marginal external costs, and naïve Pigouvian taxes may even lead to a welfare reduction compared to a non-pricing regime. It is fair to admit that research on these issues is still at an early stage, but it is important to convey this message clearly.

A plausible strategy to support implementation of pricing in relation to these kinds of measures could include investment in road capacity and in public transport capacity in the short term, in order to reduce acceptability problems and induce shifts between routes and modes. In the medium term, there for instance may be needed increased direct (i.e. non-price) public control of conditions for privately provided parking. And in the long term, in order to support the anticipated highly technical solutions for pricing, there may be need for information systems indicating road toll and fare structures for drivers and passengers. The modelling case studies however did not consider these issues.

Two case studies did consider (Helsinki, Oslo) long-term impacts on land use (and through land use changes). The results, besides providing a more comprehensive picture of the impacts of pricing policies in the long run, and demonstrating the importance of accounting for land use changes when designing implementation paths for marginal social cost pricing, also provided important insights for the coordinated use of land use policies along with transport pricing policies.

As for institutional reform, on a general level, the relevant issues include the choice between centralisation vs decentralisation and privatisation vs government control. Marler et al (2003) and Adler et al (2003) concluded (again not very surprisingly) that the relevant institutional structures in relation to these issues greatly vary between different countries. An important question is possible need for institutional reform.

There are arguments, which suggest that marginal social cost pricing can best be implemented by a very centralised approach, with transport pricing decisions taken at the level of national government or indeed the EU. Where decisions are decentralised, while different levels of government may pursue policies that are best for their own electorate, they however collectively fail to optimise for the country or EU as a whole. However, there are strong arguments in favour of decentralised decision taking in terms of stakeholder participation in democratic decision-making processes. For this reason, there is strong opposition to centralisation of decisions, which may make such an approach unacceptable anyway. Clearly some sort of compromise to achieve the best reconciliation of conflicting goals is needed.

Similar issues arise regarding the relative roles of deregulation and privatisation versus government control. An extreme approach to the implementation of marginal social cost pricing would be to seek the maximum possible degree of deregulation and privatisation, because in a (perfectly) competitive market firms are forced to implement marginal cost pricing in order to survive. Externalities may then be taken into account by the use of Pigovian taxes and subsidies. However, to the extent that market power exists, particularly in the form of natural monopolies, firms will not of their own accord implement marginal cost pricing, and government control or regulation will be needed. However, such control itself risks government failures of one form or another, as governments do not necessarily have adequate information or the motive to act in a way that will maximise social welfare.

In particular in rail, air and water transport modes alternative approaches to achieve MCP range from competitive markets under constant returns to scale to relying on state ownership and control or regulation given a natural monopoly. In-between are a range of oligopolistic practices, as associated with short sea shipping for example. The competitive equilibrium model is most applicable to freight operators and end users of all three modes of transport. This may also be true for airports that appear to work under constant returns-to-scale. Alternatively the airports could be viewed as natural monopolies and therefore be either state-owned or at least regulated. For the case of infrastructure pricing and of short-to-medium distance public transport, the state owned and/or regulated approach would appear to be preferable, in part due to the Mohring effect.

There are no simple answers as to the form of institutional reform that will be best either in terms of the achievement of marginal social cost based pricing or of the best result overall. Institutional issues remain priority for further research.

Table 6.9: Overall implementation paths by key dimensions of the pricing system (urban transport and interurban road)

Phases Key dimensions	Short term (0-3 years)	Medium term (3-10 years)	Long term (10+ years)
Technology	Simple technology used for road pricing and parking charges in urban areas but ensured that it is compatible with plans for more sophisticated technology in the future. Smart card applications in public transport in urban areas. Electronic systems, though highly incompatible, used for charging interurban roads.	Electronic road pricing (ERP), possibly GPS-based, in urban areas. Standardised ERP system, possibly GPS-based, for interurban roads throughout Europe.	GPS-based and fully standardised ERP systems for urban and interurban roads. Parking charging technology and smart card technology in public transport fully integrated with the urban road pricing system.
Coverage or scope of the pricing system ("What will be priced?")	Road pricing in central urban areas and on weekdays. Publicly controlled parking fees. Distance-based kilometre charges for heavy goods vehicles (HGV's) in certain countries. In other countries the current Eurovignette system or no road charging continues. Tolls on specific roads with congestion or financing problems.	Road pricing gradually extended but mostly restricted to central urban areas and weekdays. Increased public control of private parking fees. Distance-based kilometre charges for HGVs throughout Europe. Tolls on specific roads more common.	Road pricing on all urban links and at all times. Distance-based kilometre charges on all European interurban links for HGVs, road public transport and private vehicles.
Composition (mix) and level of pricing measures ("How will be priced?")	Area-based charges (incl. cordon tolls) in central urban areas and on weekdays. Publicly controlled parking fees increased where required to cover induced costs. Public transport fare structures and subsidies adjusted according to second-best principles to be in line with area-based charges for cars. In some cases distance-based kilometre charges for HGV's may need to be compensated by reductions in other taxes (fuel taxes and vehicle licenses).	Distance- based road pricing replaces area-based charges in urban areas. Charges gradually moving towards pricing relevant marginal social costs. Further adjustment in public transport fares and subsidies as distance-based road pricing phased in. Fuel taxes and vehicle licenses gradually reduced, as distance-based ERP phased in.	Distance- and GPS-based ERP phased in on all urban links and at all times. Public transport fares and subsidies fully adjusted (levels). Fuel taxes reduced to cover CO_2 emissions costs only. Vehicle licenses further reduced, in some cases (but not in all) ultimately to zero.
Degree of differentiation of pricing measures	Parking fees by location and time. No differentiation of distance-based kilometre charges for HGV's within country by time or space.	ERP non-differentiated. Publicly controlled parking fees more disaggregated by location and time. Tolls on specific roads differentiated by time of day. Charges gradually moving towards pricing relevant marginal social costs.	ERP charges for all traffic ultimately according to full marginal social cost based differentiation. Publicly controlled parking fees fully disaggregated by location and time. Same for private parking where possible.
Rules and principles governing revenue use	Earmarking to allow for acceptability and funding problems and thus facilitate implementation.	Earmarking less important.	
Use of supplementary non-price measures	Investment in road and public transport capacity to support implementation.	Increased public control (non-price) on conditions for privately provided parking.	Information systems indicating fare structures for drives and passengers.

Table 6.10: Phasing-in of measures in urban transport

Phases Key dimensions & second-best constraints	Phase 0 (current situation)	Phase 1 (short term, 0-3 years	Phase 2 (medium term, 3-10 years)	Phase 3 (long term, 10+ years)
Coverage or scope of the pricing system	General lack of integration of external and infrastructure costs in prices. Great national and local variation in the integration of these costs.	Step tolls on selected links. Area-based charges (incl. cordon tolls) in central urban areas and on weekdays.	Distance based electronic road pricing (ERP) road pricing for private cars and heavy good vehicles (HGVs) replaces area-based charges. Charges include infrastructure damage and emissions. Pricing still restricted to central area and weekdays.	Distance and GPS based ERP on all urban links and at all times for all vehicles and targeted at all major externalities, including congestion (road and parking), emissions, accidents and noise.
Composition (mix) and level of pricing measures	Generally three-part tariff comprising: vehicle tax, annual license fee, and fuel tax. Parking charges, also as substitute to road charging. Direct road user charges, i.e. road tolls, area licences and the like only in a few cases. Very different pricing systems across countries.	Step tolls, Area based charges, Cordon tolls, Parking fees, Fuel taxes Fare structures with minor changes to existing ones. Publicly controlled parking fees increased where necessary to cover induced costs. In public transport fare structures and subsidies adjusted to be in line with area-based charges for cars. Fuel taxes affected by intermodal considerations.	Area based charges, Cordon tolls, Parking fees, Fuel taxes, Electronic distance based road pricing using GPS Global position System). Integrated fixed & variable usage charging schemes (two-part tariffs) Pay-As-You-Drive Vehicle Insurance Public transport fare second-best and integrated with the road pricing system. Further adjustment in public transport fares and in public transport subsidies as distance-based ERP phased in. Charges gradually moving towards pricing relevant marginal social costs.	Electronic distance based road pricing using GPS Road pricing and fares broadly first-best. Public transport fares integrated with the road pricing system Public transport fares and subsidies fully adjusted (levels) and smart card technology integrated with concurrent GPS-based ERP road pricing system.
Degree of differentiation of pricing measures & charging technology	Practically no differentiation in time and space and by vehicle type. Users pay irrespective of the infrastructure damage, congestion and pollution they cause. In public transport, fares differentiated by journey length, mode and operator where a commercial decision. In most cases simple flat or zonal fares. Also travel cards giving	Cordon tolls static. Cordon tolls and step tolls anonymous and based on PCEs (Passenger Car Equivalents). Publicly controlled parking fees by location and time (also by duration), and increased where necessary to cover induced costs. Simple technology used but ensured that it is compatible with plans for more sophisticated technology in the future.	Cordon tolls dynamic. Distance based electronic road charges ERP anonymous, GPS-based and based on PCEs and/or vehicle type User charges for emissions differentiated by vehicle type. Integrated fixed & variable usage charge schemes (two-part tariffs). Pricing partially integrated with ATIS (Advanced Travel	Distance based road pricing non-anonymous and based on vehicle type & condition and, possibly, driver characteristics. Road pricing fully integrated with GPS and ATIS. Publicly controlled parking fees fully disaggregated by location and time. Same for private parking when possible. Parking charging technology ultimately integrated with the GPS-

	unlimited travel for certain period of time.	In public transport minor changes to existing fare structures (fare cards, peak/off-peak differentials, reductions for selected groups). Application of smart card technology.	Information Systems). Publicly controlled parking fees more disaggregated by location and time. Smart card technology for public transport integrated with (technologically) concurrent road pricing system.	based ERP system. Ultimately non-anonymous charges according to full marginal social cost based differentiation. Public transport fares and subsidies fully adjusted (levels) and smart card technology integrated with concurrent GPS-based ERP road pricing system.
Rules and principles governing revenue use	Vehicle purchase taxes, annual license fees and fuel taxes to state budget. Road user charges earmarked where collected. Public transport fares to cover cost of service production.	More hypothecation.	More hypothecation.	How much hypothecation also a political choice.
Use of supplementary non-price measures	Infrastructure investments common to alleviate congestion problems.	Infrastructure given Complementary public transport measures. Alternative work schedules (*e.g.* staggered work hours, flextime, compressed work weeks, telecommuting), complementary public transport measures (Dial-a-Ride, minibuses, taxi service improvement, *etc*.).	Infrastructure partially adjusted: investment in public transport and road infrastructure. Increased public control of private parking (fees and other conditions). Alternative work schedules.	Infrastructure fully adjusted to optimum. Information systems indicating fare structures for passengers in public transport. Alternative work schedules.

Table 6.11: Phasing-in of measures in interurban transport: road, rail, air and water

Phases Key dimensions & second-best constraints	Phase 0 (current situation)	Phase 1 (short term, 0-3 years	Phase 2 (medium term, 3-10 years)	Phase 3 (long term, 10+ years)
Coverage or scope of the pricing system	Road: 3 Europes (Eurovignette, free roads, toll roads). All countries have fuel taxes and annual licence duty Rail: All countries required to have charges for infrastructure use. In some countries a MC-based, two part (or multi-part) tariff with fixed element based on unavoidable costs and an allocation of joint costs and a variable element based on wear and tear and electric traction costs. Air: Airport pricing includes landing fees according to maximum take-off weight of aircraft, transfer and non-transfer passenger departing fees, air traffic control tariffs, parking fees, freight loading/unloading charges, security and control charges for passengers and freight and at certain airports, night charges, noise fees and peak fees. Separate concessions and gate fees are collected for landside operations.	Road: Some countries will implement HGV kilometre based charges ahead of EC legislation Rail: No changes currently to allow other modes to reach MCP schemes already in place for rail transport. Air: Initiate use of peak-off peak, congestion and noise pricing mechanisms at large, hub airports. Gradual implementation of existing directive Water: Introduce route or distance based charge with differentiation according to vessel type and emission factor to account for marginal infrastructure costs and emissions of local pollutants.	Road: HGVs generally charged per km (Euro legislation). Tolls on specific roads (congested or expensive new construction) more common Rail and air: MCP excluding scarcity and congestion Air: Initiate use of peak-off peak, congestion and noise pricing mechanism at all airports, in a neutral manner. Introduce fuel taxes to account for NOx and CO_2 emissions, on at least an E.U. wide basis. Encourage discussion on a worldwide basis to prevent airlines from refuelling at tax-free refuges. Rail and water: Full marginal social cost pricing including wear and tear and environmental costs but not scarcity and congestion or accidents. In a slower variant (for all three modes): km charges covering wear and tear only.	Road: Full GPS based (ERP) marginal social cost pricing for HGVs on all roads Rail and water: Full marginal social cost pricing (including scarcity, congestion and accidents). Air: Use MCP mechanism without constraints. Introduce scarcity charges through market-based slot allocation mechanism. Introduce accident charges.
Composition (mix) and level of pricing measures	Road: Mix of vehicle excise duty, fuel tax, tolls, vignette. Vignette price must not exceed infrastructure cost Rail and air: Some countries under charging, others over charging relative to marginal social cost. Water: Port fee based on vessel type and destination, location of operations in the port, total processing time at port and season. Inland waterways: Harbour and lock dues	Road: Mix of Vehicle excise duty, fuel tax, specific tolls, vignette for heavy vehicles, kilometre based charges Reduce fuel taxes as other charges introduced.	Road: km charge with other taxes reduced to compensate. Tolls more common; charges revenue neutral. Reduce fuel taxes as ERP with MCP is phased in. Rail and water: MCP of operations and environmental cost but not scarcity and congestion. Second best adjustments for under pricing on roads where relevant	Road: Fuel tax reduced to cover CO_2 costs only. Vehicle excise duty abolished. Reduce vehicle licences ultimately to zero, as ERP with MCP phased in. Two alternative scenarios: remaining revenue neutral; full marginal social cost pricing. Road, rail and water: full marginal social cost pricing.
Degree of differentiation of pricing	Road: In some countries supplementary charges for motorways Rail: some charges highly differentiated in time and	Road: No differentiation within country by time or space Rail: Differentiated by location	Road: Tolls more differentiated by time of day Rail: Differentiated by location	Full differentiation on all modes by time and location

measures & charging technology	space.			
Rules and principles governing revenue use	Rail: All receipts generally devoted to rail infrastructure	Road: Cross-subsidisation between modes	-	-
Use of supplementary non-price measures	Rail: EC directives, vertical separation. Investment, including investment in rail to relieve road congestion and environmental cost. In some cases, schemes include penalty payments/bonuses based on performance criteria, accident charges, congestion charges and information charges.	Rail: Agree amongst EU countries on removal of organisational constraints. Air: Harmonise state legislation according to EU legislation, define delay legally and set-up EU-wide database for all airports.	-	-

7 LIST OF DELIVERABLES

Table 7.1 shows the MC-ICAM deliverables.

Table 7.1 List of Deliverables

	Title
D1	"Setting the Stage"
D2	"Relevant Optima and Constraints"
D3	"Modelling & Cost-benefit Framework"
D4	"Modal Aspects – Urban and Interurban Road"
D5	"Modal Aspects – Rail, Air & Water"
D6	"Phased Approach"
D7	"Welfare Effects – Urban"
D8	"Welfare Effects – Interurban"
	Final report

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