CONTRACT N° : GMA2/2000/32056-S12.335673

PROJECT N° : GMA2/2000/32056-S12.335673

ACRONYM : SPECTRUM

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

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PROJECT START DATE : 01/09/2002 **DURATION : 36 months**

Date of issue of this report : 17th August 2004

Project funded by the European Community under the 'Competitive and Sustainable Growth' Programme (1998-2002)

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0. Executive Summary

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

The aim of this deliverable is to design an appropriate framework of analysis of urban transport measures (regulatory, economic and physical instruments aimed at affecting private and public transport and parking facilities usage) which allows reviewing likely impacts and identifying relevant interactions between the measures: to this purpose an in-depth description of a 30 measures is provided based on evidence produced by past studies and a limited number of interviews.

The analysis carried out in this report is coherently based on the main approach and concepts developed in the first part of the project, in particular building upon:

- the high level framework described in Deliverable 5 (context and reference scenario, policy objectives and related indicators, assessment framework, classification of transport instruments)
- the theoretically sound framework for defining combinations of economic instruments, regulatory and physical measures developed in Deliverable 4 (identification of optimal packages of transport instruments, implications of equity considerations, barriers to improved transport policies)

The report focuses on a limited set of policy instruments relevant to the urban context (around 30), which are for convenience grouped in: *economic instruments* (road pricing, fuel and vehicle taxes, financial incentives to production and purchase of clean fuel vehicles, property taxation), *physical restrictions to car use* (dedicated lanes, pedestrian areas, limited access zones, car-free zones, traffic calming schemes), *urban freight distribution* (city logistic terminals, city freight management measures), *intelligent transport systems*, *infrastructure provision, maintenance and land use measures* (road infrastructure expansion, road infrastructure maintenance, new Public Transport infrastructure, development mix, landscape compatibility of infrastructure), *parking measures* (on-street parking, off-street parking, enforcement and monitoring aspects), *other public transport instruments* (bus prioritisation, service level requirements, information provision and marketing, emission standards, tariff systems, fare levels and concessionary fares, taxes, subsidies).

These instruments have been selected according to their potential for interrelationships with economic instruments, to the relevance and importance of the expected impacts (with respect to the objectives), to the relationship of the instruments with capacity management issues. A detailed description of the general characteristics of the instrument, the implementation actors and processes, the likely impacts and the interactions found with other policy instruments is provided. The analysis of the combination of transport instruments into packages follows the concepts elaborated in Deliverable 4, and considers therefore that the interaction between instruments can result in: *increasing returns to packaging of economic with regulatory and/or physical measures* or synergy, *constant returns to packaging* or additivity, *decreasing returns to packaging* or substitutability.

In accordance with SPECTRUM research interest and previous conclusions, it is deemed necessary that the case studies of the urban area have two minimum requirements:

- packages of transport instruments are built as a combination of one or more economic measures with one or more regulatory and/or physical measures;
- the analysis of packages of transport instruments takes into account at least the markets of private motorised transport (car) and public transport, in order to allow a correct estimation of efficiency gains/losses[1].

The SPECTRUM approach to the study of the interaction of transport instruments in urban context adopts as the main assessment criteria the impacts on welfare, aiming to assess how the consumer and producers welfare is affected, and how government welfare and external costs change, due the implementation of packages of transport instruments. In order to achieve the overall goal of assessing the extent to which economic instruments can be substituted for or work in synergy with other instruments, SPECTRUM will proceed tacking stock of the information provided in this deliverable – mainly based on the review of past studies and experiences – and moving a step forward to form and test in real case studies packages of urban transport instruments. The formation of these specific packages of economic and other instruments in the various case studies may answer to a common set of "high level" questions as follows:

1. What level of the economic instrument is needed to replicate or improve the benefits of current measures (where current measures may be economic or other types)?
   - Is the economic instrument feasible in terms of political acceptability?
   - Does it have negative side effects in terms of any of the impact indicators in the SPECTRUM assessment framework?
   - Is the instrument practical (in terms of actual implementation)?
   - Does the instrument have particular impacts in terms of equity?
   - Is the instrument too complicated to be introduced in practice?

2. If the economic instrument isn't introduced alone, but in conjunction with one or more other instruments, what levels of benefits could be achieved by the package?
   - Is the combination of economic and other instruments feasible in terms of political acceptability?
   - Does it have negative side effects in terms of any of the impact indicators in the SPECTRUM assessment framework?
   - Is the combination practical (in terms of actual implementation)?
   - Does the combination have particular impacts in terms of equity?
   - Is the combination too complicated to be introduced in practice?

The questions are aimed at addressing in practice the notions of "returns to packaging" that are identified in this deliverable – discussing in particular likely returns that may stem from some typical interactions of economic with other regulatory and physical measures - as well as, at a more theoretical level, in the previous Deliverable 4.

[1] it has to be mentioned that a correct estimation of efficiency gains/losses would be achieved only if all costs and benefits arising in related markets are taken into account, therefore all modes of transport in urban areas should in principle be included into the analysis. However, the dichotomy private-public transport is a suitable distinction for many purposes.

1. Introduction

This Deliverable is focused on urban policy instruments – economic, regulatory and physical measures – and their combination into packages of economic and other measures. It is important to remark here that SPECTRUM is not concerned with combinations of policy instruments in general, nor only with "best combinations", but rather with the results of mixing specifically economic transport instruments with other (regulatory, physical) instruments, looking for synergies (i.e. positive interactions) as well as for other possible side effects of which policy makers should be made aware.
The report follows two previous SPECTRUM deliverables, D5 and D4, which respectively set out the high level framework for transport instruments packages – both at the interurban and urban level – and the theoretically sound framework for defining combinations of economic instruments, regulatory and physical measures. The aim of the report is to move some steps ahead in the direction of applying theoretically sound concepts to solve the real and manifold problems of managing urban transport in the cities of Europe.

Taking stock of the theoretical analysis performed so far, the report reviews the following set of urban transport instruments:

- ✓ **Economic instruments**: road pricing, fuel and vehicle taxes, financial incentives to production and purchase of clean fuel vehicles, property taxation.
- ✓ **Physical restrictions to car use**: dedicated lanes, pedestrian areas, limited access zones, car-free zones, traffic calming schemes
- ✓ **Urban freight distribution**: city logistic terminals, city freight management measures.
- ✓ **Intelligent Transport Systems (ITS)**, to support traffic management and public transport.
- ✓ **Infrastructure provision, maintenance and land use measures**: road infrastructure expansion, road infrastructure maintenance, new Public Transport (PT) infrastructure, development mix, landscape compatibility of infrastructure
- ✓ **Parking measures**: on-street parking, off-street parking, enforcement and monitoring aspects
- ✓ **Other Public Transport instruments**: bus prioritisation, service level requirements, information provision and marketing, emission standards, tariff systems, fare levels and concessionary fares, taxes, subsidies.

Each urban transport instrument has been reviewed based on evidence produced by past studies and some limited interview activities, focusing on: i) general characteristics of the instrument; ii) implementation actors and processes; iii) likely impacts; iv) interactions found with other policy instruments. A detailed description of these aspects can be found in the Chapters from 3 to 9 of the report.

The following chapter 2 anticipates instead the core aspects and conclusions of the analysis of urban transport instruments. These concern the empirical evidence that the review of the measures has shown of: i) the likely impacts of the instruments taken in isolation; ii) their most frequent or likely combination into packages of two or more policies, and iii) the more relevant synergies that the "right combination of the right policies" is expected to produce. Chapter 2 clarifies also the relationship between the empirical investigation of policies illustrated in this report, and the theoretical framework provided by SPECTRUM Deliverable 4, as well as the strategy that should be used for applied urban case studies, with the aim of bridging theory with practice.

2. Combination of economic and non-economic urban transport instruments: empirical evidence

2.1 Combination of urban transport instruments: from theory to practice

As stated in the inception of Deliverable 4, the SPECTRUM project aims to develop a theoretically sound framework for defining combinations of economic instruments, regulatory and physical measures in reaching the broad aims set by transport and other relevant policies. Within this main objective, the goal is to assess the extent to which it is possible to substitute economic transport instruments with physical and regulatory instruments and to investigate evidence of synergy and complementarity between the instruments.

Building upon the existing theoretical and applied literature, the specific objectives fulfilled by Deliverable 4 (D4) were:

- to determine theoretically optimum packages in terms of the high level objectives formulated in SPECTRUM Deliverable 5: economic efficiency, environment and health, safety and security, intra-generational equity, inter-generational equity;
- to identify the most important barriers to optimal packages.

Taking the welfare economic theory approach, D4 has determined - on the basis of a welfare function including consumers, producers, government welfares and external costs - four types of interaction between measures: complementarity, additivity, synergy and perfect substitutability. One main conclusion of this theoretical analysis was to acknowledge that the extent of interaction between different instruments can only be evaluated when these instruments are optimised subject to given constraints, and as consequence the case studies (and in particular the urban case studies) should consider as much as possible optimal second-best policies. A classical example of second-best optimal policy, mentioned in D4 (at page 3), is the toll that maximises welfare given that one cannot differentiate the toll fee between the peak and the off-peak period.

Other practical conclusions came from the review of applied studies investigating the effects of combinations of instruments in policy packages illustrated in D4[2]. Briefly, these studies have demonstrated that:

- Efficiency gains are increased when the packages of transport instruments include: i) instruments that are differentiated by the time of the day; ii) public transport fares and frequencies adjustments coupled with increases in the cost of car travel; iii) low cost capacity improvements; iv) road pricing.
- Environmental and safety benefits are increased when packages include: i) fuel tax; ii) introduction of cleaner technologies; iii) road pricing; iv) road pricing and/or increased parking charges.

It is important to note that these increase in benefits, although mainly caused by the application of economic measures, are in some cases strengthened by the concomitant implementation of physical capacity measures or regulatory measures. It is now the aim of

[2] These include OPTIMA, FATIMA, AFFORD, PROSPECTS, TRENEN, Historic Cities and London Congestion Charging.

this Deliverable to further exploit these first insights, providing a systematic review of the urban transport instruments and their likely interactions in a greater detail.

In order to enlarge the field of investigation, we decided to use a concept of "combination of policy instruments" wider than the (more rigorous) concept stemming from the welfare theory, which is in any case included in the wider definition illustrated below.

According to the PROSPECTS Decision Making Guidebook (PROSPECTS 2003), an urban policy instrument is any tool which can be used to overcome problems and achieve objectives, and it may include transport as well as land use policies. However, isolated application of individual policy instruments is becoming a rarity. Indeed, the quest for combining policy instruments into coherent packages to tackle with complex urban problems is growing, based on the assumption that the objectives can be achieved more effectively by using *packages of policies*, whereby the combination of complementary and mutually supportive measures *facilitates their implementation* and/or *intensifies the respective impacts*.

Following the TRANSPLUS Project Guidelines (TRANSPLUS 2003), it is possible to further specify the concept of "combination" identifying the following types:

1. *Coordination of a given set of policies (e.g. parking) over time and space*, e.g. over different day times and/or across different jurisdictions. This first level of coordination is especially important when certain measures must be implemented on a large scale by different jurisdictions in order to be effective.

2. *Coordination of physical, regulatory/organisational and economic measures in the same field of intervention* (e.g. land use development, transport infrastructure development and use, vehicle technologies, application of information technology to transport). This second level of coordination is usually required because measures in the same field are related to the same object (e.g. cycling) and should meet a coherent set of objectives.

3. *Coordination of measures of the same nature – physical, regulatory/organisational, economic – across the different authorities responsible at the local, regional and national level*. This third level of coordination assumes a special relevance whenever the competence for a certain type of measures (e.g. taxation) is distributed between different tiers of authorities.

4. *Combination of single measures into packages* where the mutual interactions between the different measures are strengthened (as might be evaluated using the welfare function proposed in the high level framework of SPECTRUM).

5. *Integration of institutions and/or processes* with formal or informal co-operation rules and mechanisms or through amalgamation.

To find the right combination of transport instruments which work well in a given context we need to identify those mutual interactions between the economic and non-economic instruments that make the results of the whole package better than those achievable with the separate application of the policies. However, in any given context of application, the requirements concerning a better integration of the institutions and processes of implementation of those measures cannot be overlooked, although these implementation aspects will not be the main focus of the analysis undertaken in particular in SPECTRUM.

The latter will concentrate instead on the study of the mutual interactions of the urban transport instruments to be combined into packages, which may be classified into the following categories:

- *Benefit enhancing*: a measure reinforcing the benefits of another;
- *Acceptance enhancing*: a measure making another more acceptable for the citizens and/or stakeholders (e.g. specific provisions to compensate losers);
- *Resource providing*: a measure providing more financial or technical resources for the implementation of another measure;
- *Pre-requisite* for implementation (e.g. compact land use is a pre-requisite for the viability of car sharing).

For instance, an example of 'resource providing' interaction is the combination of light rail and road pricing. The latter encourages greater use of light rail and generates revenue to pay for the light rail. Furthermore, the use of revenue to invest in light rail makes road pricing more acceptable and provides alternatives for those no longer driving, which gives an illustration of an 'acceptance enhancing' (PROSPECTS 2003). As shown in this example interactions between pairs of measures are not necessarily symmetrical: road pricing is resource enhancing for light rail, while light rail is acceptance enhancing for road pricing. Moreover, the time sequence really matters, and some time there may be serious "chicken and egg" problems. For instance, if there is a shortage of financial resources, road pricing should come before public transport improvement, to provide resources for new Public Transport (PT) services, infrastructure etc.. But, unless an effective information campaign will have raised the confidence and acceptance of citizens, they will not be ready to accept road pricing without seeing an immediate counterpart in terms of better public transport services.

An example of 'pre-requisite' is the relationship between compact urban development and strategic location of car sharing facilities. Compact cities and sub-centres reduce the need to travel by car, and this facilitates the adoption of car sharing schemes which are usually convenient only for low-level car users living in the vicinity of car sharing facilities (TRANSPLUS 2003).

In conclusion, a good package of policies should be realised including not only the right elements - the individual transport instruments - but also implementing the right relationships between the instruments. It is clear that if a city is implementing, for instance, some form of parking charge scheme together with a programme of PT service quality improvement, but the revenues from road pricing are not used to finance the PT investments, or, even if revenues are used, citizens are not aware of this, the acceptability of the whole policy may be reduced.

Table 1 below is taken from TRANSPLUS 2003. It provides an overview of urban transport instruments classified by field of intervention (the rows) and kind of measure, i.e. physical, regulatory/organisational or economic (the columns). In the following section we will focus on the "menu" of more specific transport policy instruments considered in SPECTRUM.

Table 1: Urban Transport Policy Instruments

Field of intervention		Kind of instrument		
Supply	**Use**	**Physical**	**Regulatory**	**Economic**
Land use		▪ Brownfield development ▪ Mixed-use development ▪ PT oriented development ▪ Pedestrian and cycling friendly site development ▪ Decentralisation of non-service employment ▪ Decentralisation of retail	▪ Location policy (ABC-like) ▪ Protection of sites from development (green belt) ▪ Road corridors development control ▪ Transfer of development rights ▪ Building regulation, building permits ▪ Density standards ▪ Purchase, pre-emption rights	▪ Land taxation ▪ Value capture ▪ Development in-kind requirements ▪ Public land banking ▪ Developer fees ▪ Development funding, disbursements
Infrastructure (transport networks)	Walking	▪ Creation of pedestrian areas	▪ Car free zones	
	Cycling	▪ Expansion of existing bike lanes		
	Individual car use	▪ Expansion of existing road network ▪ Road maintenance and clearing priority ▪ Traffic calming facilities ▪ Access control devices ▪ Designation of on-street parking supply	▪ Restricted access at certain times ▪ Restricted access to certain types of vehicles ▪ Speed limits ▪ Parking time constraints ▪ Enforcement of parking measures ▪ Parking regulations in building codes ▪ Regulation of off-street parking supply ▪ On-street parking time restrictions	▪ Road pricing ▪ On-street parking pricing ▪ Off-street parking pricing
	Car pooling	▪ Dedicated HOV lanes	▪ Company mobility plans	
	Taxi	▪ Dedicated lanes	▪ Licensing	
	Public buses	▪ Bus lanes	▪ Bus prioritisation ▪ Quality regulations ▪ Information provision and marketing	▪ PT fare level ▪ PT fare structure ▪ Concessionary fares ▪ Subsidies to operators
	Trams, light rail, rail and metro lines	▪ Expansion of existing network	▪ Quality regulations ▪ Information provision and marketing ▪ Tram prioritisation	
Infrastructure (transport terminals)	Bus stations	▪ Expansion of park & ride lots		
	Railway stations			
	Metro stations	▪ Park & ride facilities ▪ Bike & ride facilities		
	Freight terminals	▪ Building/ expansion of terminals for city freight distribution		
Vehicle fleets	Private vehicles		▪ Pollutant and noise emission standards	▪ Fuel taxes ▪ Vehicle ownership taxes ▪ Incentives for alternative fuels vehicles ▪ Variable vehicle-related fees
	Public buses			▪ Fuel taxes ▪ Incentives for alternative fuels vehicles
Information technology	Private transport	▪ ITS driver information		
	Public transport	▪ ITS driver information ▪ ITS fleet management and control ▪ ITS real-time passenger information system		

Source: TRANSPLUS (2003)

2.2 Overview of the urban transport policy instruments investigated in SPECTRUM

The aim of this deliverable is to provide an in-depth review of urban transport measures – i.e. regulatory, economic and physical instruments aimed at affecting private and public transport and parking facilities usage - with particular reference to reviewing likely impacts and identifying relevant interactions between the measures themselves, based on evidence produced by past studies and some limited interview activities.

A restricted group of about 30 instruments has been sorted out from the broad list of transport policy instruments included in SPECTRUM D5 and further investigated. The choice of the subset of instruments has been made on the basis of the following criteria:

- Potential for interrelationships with economic instruments;
- Relevance and importance of expected impacts (with respect to the objectives);
- Relationship of the instruments with capacity management issues;
- Relevance to the urban context.

For each instrument the subsequent chapters illustrate in detail the following elements: i) general characteristics of the instrument; ii) implementation actors and processes; iii) likely impacts; iv) interactions found with other policy instruments.

Based on the detailed findings presented in the deliverable, we have drawn a synoptic view of the most likely impacts of the single instruments, of the most frequent or possibly relevant interactions with other instruments and of the relevant synergies[3] observed between the measures. This is shown in the table below.

It is important to note that the measures surveyed can have short term as well as medium-long terms impacts. Some measures – e.g. land use planning or infrastructure provision – have clearly medium-long term impacts and almost no short term consequences (although possible short term aspects are related to the need of finding budgetary resources “today” for financing investments in infrastructures that we will manifest their impacts on the transport system “tomorrow”). Other measures have mostly short terms impacts, as it is the case for example for road infrastructure maintenance, although even in this case the upgraded infrastructure resulting from maintenance activities will produce medium-long term benefits for the users of the road network.

The time horizon has been considered in the synoptic table by including a column near that listing the likely impacts of the measures, to indicate if the expected impact is on the short-term (S) or medium-long term (M). This time horizon refers to time most likely needed for the effect to manifest since the measure has been put in place.

[3] The concept of “synergy” has been defined in SPECTRUM Deliverable 4 as the situation which occurs when the combination of two or more measures gives a greater welfare benefit than the sum of the benefits of using either one of them alone (see also section 2.3 of this deliverable)

Table 2: Synoptic view of urban transport instruments

Policy instruments	Likely impacts	Time horizon	Interactions with other economic measures	Interactions with other non economic measures	Relevant synergies
Road pricing	- Efficiency gain - Revenue raising - Equity impacts strongly dependent on revenue recycling	S S M	- Fuel taxes - Parking charges - Car taxes - Public transport fares - Other economic measures	- Infrastructure provision - Car restriction measures - Land use	- Key ingredient in combination of policies design to increase the efficiency of urban transport systems - A main side-effect is the transfer of large sums of money from travellers to government coffers and the impact of recycling
Fuel taxes	- Raising revenue - Decrease of car use, fuel consumption and emissions - Improves fuel efficiency and fuel efficient car fleet - Decrease congestion (more limited effect) - Increase the use of alternative modes - Equity impacts	S S M S S M	- Vehicle taxes - Road pricing - Public transport fares - Other economic measures	- Regulatory measures on fuel and vehicles - Infrastructure provision	- An important ingredient in an urban package of instruments, especially in the presence of second-best road pricing (toll ring scheme).
Vehicle taxes	- Decrease of car ownership - Increase in fuel efficiency of the car fleet (if linked to the size/type of engine) - Revenue raising	M M S	- Fuel taxes	- Regulatory measures on fuel and vehicles - Public transport provision	- An important instrument for the promotion of a fuel efficient vehicle fleet
Financial incentives to clean fuel vehicles	- Increase fuel efficiency of the car fleet - Decrease emission of greenhouse gasses and other pollutants	M M	- Fuel taxes - Vehicle taxes	- Regulatory measures on fuel and vehicles - Traffic calming measures	- An important instrument for increase in fuel efficiency of car fleet and the reduction in greenhouse gasses
Property taxation	- Raising revenue for transport and other infrastructure provisions - Promotion of a desired land use pattern	M S	- Fuel taxes - Other economic instruments	- Regulatory measures on land use - Infrastructure provision	- The instrument may have an important influence on urban development patterns

Policy instruments	Likely impacts	Time horizon	Interactions with other economic measures	Interactions with other non economic measures	Relevant synergies
Reallocation of road space by dedicated lanes	- Decrease of travel time; Increase in punctuality and reliability of PT - Reduction of costs of operation - Decrease in demand for car travel and increase in public transport, walking and cycling - Reduction of the number, severity and risk of accidents	S S M S	- Urban road pricing - Parking charges - PT fares	- Urban traffic control (UTC) and PT fleet management systems - Park&ride schemes - ITS - Traffic calming	- Combined with traffic management measures, adverse impacts on accessibility can be minimised and safety increased
Restriction of car use by pedestrian areas, limited access zones, car free zones, traffic calming, parking space limitation	- Formation of less car-dependent communities (attractive, safe and suitable for walking) - Reduction of traffic (within the area) - Considerable reduction of NOX, HC, PM, CO, SO2 and CO2 emissions (within the area)	M S S	- Parking charges - Road pricing	- Public Transport improvements and development - Non-motorized transport improvements - Car-sharing	- Disincentives to driving and improvements to walking, cycling and PT can avoid the shifts of car trips to other parts of the urban region - Liveable communities may have important synergies with other urban policies (e.g. social policies, crime control)
City logistic terminals	- Reduction of pollutant emissions - Shift of long distance transport from road to rail - Stimulation of economic growth (new jobs, increased trade) - Increasing freight vehicles movements within the city (small deliveries)	S M S / M S	- Road pricing	- City access and urban planning regulations	- Improving logistic strategies for small and medium sized enterprises - Providing the necessary terminal infrastructure guarantees the efficient access to the multimodal transport network

Policy instruments	Likely impacts	Time horizon	Interactions with other economic measures	Interactions with other non economic measures	Relevant synergies
City freight management measures	- Improvement of accessibility and circulation - Reduction of emissions - Enhancement of the safety of the traffic system - Increase in competitiveness of transport companies and logistic service providers	S S S M	- Road pricing	- Network strategies (route or road area bans for trucks) - Loading/unloading, curb-side use, off-street facilities and truck parking facilities	- New strategies, chiefly based on the provision and use of ICT systems and tools can boost a more efficient urban freight management
Intelligent Transport Systems (ITS)	- Improved public transport conditions - Reduced journey time - Improved reliability and use of less-congested roads - Promotion of local economic growth - Protection of environment (reduction of air pollution) - Better equity and social inclusion - Enhancement of safety (reduction in the number of road casualties)	S S S / M M S / M M S / M	- Parking charges - Road pricing	- Ticketing and tariff systems	- Urban traffic control (UTC) systems integrated with ITS proved working efficiently - Bus prioritisation is more efficient if implemented through ITS devices
Road infrastructure expansion	- Expected growth of car use - Increase in travel speed - Urban sprawl - Bigger catchment areas for retail & leisure centres - Increasing average travel distance	M S M S / M M	- Road pricing	- Land use planning	- Strong feedback loop between capacity of road network and car-use - Road pricing may curb peak-load demand and the need for new infrastructure - New road infrastructure can be partly financed with future toll revenues (more limited case in the urban context)

Policy instruments	**Likely impacts**	**Time horizon**	**Interactions with other economic measures**	**Interactions with other non economic measures**	**Relevant synergies**
Road infrastructure maintenance	- Variable effects on the traffic flow (similar to those of traffic calming facilities) - Capacity loss (strongest impact) - Congestion and re-routing of traffic - Accident risk - Traffic redistribution in the neighbour streets - Benefits from upgraded road infrastructure	S S S S S M	- - Road pricing	- Traffic-regulating measures - On-street parking (available space for parking purposes)	- Road maintenance activities often influence the on-street parking possibilities and the available space for parking purposes. - As far as upgrading of infrastructure produce a betterment of the road network similar (although less intense) to that of road infrastructure expansion, road pricing might be used finance infrastructure maintenance as well (although acceptability is dubious)
Land use measures	- Encourage less personal motorised travel resulting in decreased fuel consumption & emissions. - Increase accessibility - Improve efficiency - Revenue raising - Brownfield redevelopment - Influence the urban structure	M M M M M M	- Road pricing - Land taxation - Property taxation	- Infrastructure provision - Car restriction measures - Public transport provision - Parking measures - Company travel plans	- A combination of policies can achieve a more sustainable environment and transport system - Barriers to acceptability can be reduced by using a package of measures - Taxation revenue can be recycled
On-street parking fees	- Improve efficiency on parking market - Reduction in and rescheduling of car trips - Indirect effect on congestion - Impact on off-street parking fees - Relatively low implementation costs - Extra revenue from parking fees	S S / M S M S S	- Other economic transport measures	- Parking supply - Enforcement of parking policies - Infrastructure provision	- Can provide second-best means of reducing congestion in a word without a full set of road tolls or with imperfect road tolls Joint optimisation of on-street parking fees, on-street parking supply and enforcement
Reducing on-street parking availability (time restrictions)	- Reduction in car trips - Less efficient allocation of parking demand to supply (as compared with on-street parking fees)	S / M S	- On-street parking fees - Other economic transport measures	- Enforcement of parking policies	- Joint optimisation of on-street parking fees, on-street parking availability and enforcement

Policy instruments	Likely impacts	Time horizon	Interactions with other economic measures	Interactions with other non economic measures	Relevant synergies
Workplace parking fee	- Indirect effect on congestion - Effect on labour supply	S / M M	- Other economic transport instruments - Labour tax		-
Enforcement of parking policies	- Better performance of parking policies - Enforcement costs - Revenues from fines	S S S	- On-street parking fees	- On-street parking supply	- Joint optimisation of on-street parking fees, on-street parking supply and enforcement
Bus prioritisation	- Increase in quality and reliability in terms of reduced travel time, punctuality, and less stops - More efficient use of the bus fleet - Reduction of operation costs .	S S S	-	- Bus or HOV lanes - UTC timings - Other management and information systems - New PT infrastructure	- Key role played in traffic management measures to substantially reduce congested traffic and to enhance more reliable journey times.
Tariff system, fare levels and concessionary fares	- Encouragement to people to use public transport. - Impacts on PT demand and consequently on price elasticity (relationship between change in passengers due to change in fares)	S M	- Individual fare levels - Road pricing	- Park & ride ticket integration	- Electronic ticketing systems applied to PT tariff and fare provided uniform database for revenue distribution for PT operators; enabled more flexible and fair tariff systems.
New PT infrastructure	- Attraction of new users from other modes - Mobility increase (if accessibility is improved) - Improvements in level of service (higher speeds enabled). - More benefits to special groups, like the elderly and disabled. - Improvement to the image of PT.	S / M M S S S / M	- Changes in tariff systems and prices	- New information systems and other intelligent transport systems - Service level improvements	- Crucial element of the transport network (bus priority measures and interchanges all need to be improved to make public transport attractive)

Policy instruments	Likely impacts	Time horizon	Interactions with other economic measures	Interactions with other non economic measures	Relevant synergies
PT information provision and marketing	- Easy choice of PT - More convenient and less stressful travelling (5%-25% increase in public transport trips) - Ticket income increase	S S / M S / M	- Tariff systems and fares	- New and/or better services and infrastructure (like increased frequency, new lines and terminals) - Bus prioritisation schemes - Reduction of car use (limited access zones, etc.).	- Strong involvement of a substantial number of actors (PT operators, planning authorities, researchers and IT providers. PT operators' associations, environmental pressure groups and employers, marketing and advertising agencies)
Legislation on PT emission standards	- Possible increase of the cost of operating the PT system - Decrease in pollution levels - Decrease in energy consumption and noise	M M M	- Possible base for different taxation of PT vehicles.	- Possible base for different prioritisation of PT low emission vehicles in residential areas.	- The need to adapt technologies to new standards may strengthen co-operation between authorities, transport operators and suppliers of technologies
PT taxes and subsidies	- Affects the characteristics of the fleet, the cost of operation and fare levels - Lower taxation and/or increased subsidies may lead to decrease of fares or better public transport services offered by PT operators - Service to areas of low transport demand is guaranteed by subsidies - Equity impacts	S / M S / M S / M M	- PT fares	- PT level of service	- Taxation of cars and other markets may be earmarked for use for public transport subsidy and thus have a direct impact.

Policy instruments	Likely impacts	Time horizon	Interactions with other economic measures	Interactions with other non economic measures	Relevant synergies
PT service level requirements	- Guarantees the passengers a clearly stated minimum level of service, safety and security - Positive market response to the realisation of improved quality measures	S M	- Tariff system and fare levels	- Restriction of car use measures - More effective and simple PT information provision	- A high public transport service level is essential for customer satisfaction

2.3 The SPECTRUM framework for the analysis of urban transport policy packages

Taking stock of the general theoretical framework for the analysis of optimal packages of transport instruments provided by SPECTRUM Deliverable 4 – and of the further implications related to equity issues and the presence of barriers to the implementation of the optimal policy packages illustrated therein – a framework for the analysis of packages of economic, regulatory and physical measures is introduced in the following, with the aim of providing a reference framework for the creation of specific packages of economic and non-economic instruments to be tested in concrete urban case studies.

According to this framework, the analysis of packages of urban transport instruments should take into account:

- the welfare impacts on the four categories of stakeholders considered in SPECTRUM: consumers, producers, government, non users;
- the costs of the measures;
- the acceptability of the measures;
- the presence of barriers to implementation of the measures and the costs of removing them.

In the context of SPECTRUM, a policy package is defined more specifically as any combination of one or more economic measures (e.g. congestions pricing, parking charges, fuel taxes, subsidies to public transport) with one or more regulatory (e.g. speed limits, emission standards, safety standards, restrictions on car use) and/or physical measures (e.g. expansion of road capacity, new public transport lines, Intelligent Transport System).

Then, the main goal of SPECTRUM is to analyse the interaction between the economic measures and the regulatory and/or physical measures. We may denote with A an economic measure (or more often a sub-package of economic measures) and with B a regulatory or physical measure (or more often a sub-package of regulatory and/or physical measures). According to SPECTRUM D4 definitions, a positive interaction between A and B or "synergy" occurs when their simultaneous use gives a greater welfare benefit than the sum of the benefits of using either one of them alone:

Welfare gain (A + B) > Welfare gain A + Welfare gain B

This synergy creates a condition that we may feature as "*increasing returns to packaging of economic with regulatory and/or physical measures*".

On the same line of reasoning, SPECTRUM D4 defines as pure "additivity" of measures, without any interaction, the situation where the welfare gain from the use of the combination is equal to the sum of the welfare gain of using each in isolation:

Welfare gain (A+B) = Welfare gain A + Welfare gain B

This additivity is equivalent to a condition of "*constant returns to packaging*".

Finally, a situation of "*decreasing returns to packaging*" occurs when the welfare gain of the simultaneous use of A and B is smaller than the sum of the benefits of using either one of them alone:

Welfare gain (A + B) < Welfare gain A + Welfare gain B

A special case of decreasing returns to packaging is the "perfect substitutability" discussed in SPECTRUM D4, and denoting the case where:

Welfare gain (A+B) = Welfare gain A = Welfare gain B

In this case, the inclusion of new measure (A or B, the relation is symmetrical) doesn't add anything to the total welfare, while in the more general case that we have labelled decreasing returns to packaging it adds something, but this is still less than the welfare gain obtainable by the any of the two measures in isolation (we might even define this situation as an "imperfect substitutability" case, where the welfare impacts of two measures partially overlap when combined).

So, the leading criteria in the analysis of packages of urban transport instruments shall be to determine the efficiency of packages looking at their welfare impacts, and observing how the consumers and producers surplus, as well as government welfare and external costs, change. The computation of these welfare components – according to the theoretical framework presented in SPECTRUM D4 – is illustrated in the red boxes of Diagram A. This diagram shows the general framework that each analysis of urban policy packages should ideally consider in determining the mentioned welfare impacts.

It is important to note that, while SPECTRUM D4 only discussed the case of one transport market, implying one mode of travel (the car) and identical transport users, Diagram A considers the case of two transport markets, car and public transport. Indeed, in the urban context to model the welfare impacts of these two modes is a minimum requirement in order to have a plausible representation of the real world for the examination of realistic urban policies. It is worth to mention here an important conclusion taken at this regard from SPECTRUM D4:

"One of the main assumptions of the partial equilibrium framework outlined above (*i.e. one transport market*) was that there are no price distortions in other markets for the optimisation rules to hold. In reality this assumption does not hold, as different modes of transport are taxed and/or subsidized in different ways. This can be explained if we consider extending the partial equilibrium framework (…) to cover two modes of transport (e.g., car and public transport). If we assume that the car price is set below marginal cost (e.g., due to the inability to include external costs) then should the price of the mode that we are considering (public transport) be set at marginal cost, given that marginal cost pricing is the most economically efficient method of pricing? The argument for marginal cost pricing assumes that there are no costs or benefits arising from the change in demand in related markets. It would only be appropriate under this scenario to set the price of public transport to marginal cost if the cross elasticity between the modes is zero. If the cross elasticity is not zero then a public transport fares increase would cause certain passengers to divert to the car where price is less than marginal cost thereby causing a corresponding welfare loss. Including frequency increases in public transport in the policy package could reduce the number of passengers diverting to the car. **When the policy packages for SPECTRUM are constructed the pricing of all modes of transport included in the analysis needs to be considered to be able to assess whether efficiency gains have been obtained**".[4]

Therefore, taking the two transport markets as basic framework, the analysis of packages of urban transport instruments should ideally include[5]:

- ✓ The segmentation of the population by income groups (e.g. income quintiles) in order to highlight equity implications or – especially if data on income groups are not available – by sex, age (e.g. young, adult, elderly), location (e.g. urban, suburban, peri-urban, rural), or employment categories, in order to analyse social inclusion effects (e.g. computing accessibility indicators for the different groups).

- ✓ The analysis of modal share of private car *vs.* public transport, in relation to each relevant segment of the population.

- ✓ The analysis for each mode[6] and each population segment of both the transport volume components and the marginal internal and external costs per unit of transport. It may be noted that:
  - the transport volume is measured in term of total vehicle-kilometre and this variable is obtained as the product of three terms: number of users in the population segment, average number of trips per user, average trip length (which gives the total passenger-kilometre) divided by a fourth term, the average vehicle occupancy rate;
  - the internal costs per unit of transport (e.g. per car km) include the producer cost (in the case of private car transport these are the user direct costs), the time cost, the internal accident cost, while the marginal external costs include congestion, pollution, health impacts and safety external costs.

With the above elements in place, the analysis of packages of urban transport instruments should then proceed to:

[4] SPECTRUM Deliverable 4, *Synergies and conflicts of transport packages*, page 9 (**emphasis added**)
[5] Real WP9 case studies will be obviously constrained by concrete data availability.
[6] As stated above, the basic option will imply to distinguish two modes: private car and public transport

- determine the generalised prices of car transport and public transport, the volumes of car and PT transport and the related welfare levels in the existing situation, to be taken as the reference urban scenario. Note that this scenario will normally include existing economic, regulatory and physical measures;

- identify packages of new economic, regulatory and physical measures which are feasible in the specific urban case study. At this stage the barriers that hinder the implementation of the packages of specific policy instruments should be described, clarifying if these are embedded or contingent barriers that can be removed. In the latter case, the analysis should consider how these contingent barriers can be better removed and what are the costs of their removal[7];

- determine what would be the second-best optimal package of economic, regulatory and physical measures given the embedded barriers, but without the restrictions due to the contingent (i.e. removable) barriers identified as per the point above[8]. Note that the package should include one or more economic measures that will influence the generalised price of transport – e.g. road pricing, parking charges, subsidies to public transport – <u>and</u> one or more regulatory measures that may affect generalised price components (user costs, time costs, accident risks), transport volume components (No. of users, average number of trips, average trip length, vehicle occupancy rate), running costs of producers, external environmental costs and, last but not the least, transport infrastructure capacity (when investments in new roads or public transport improvement will be undertaken). The regulatory and physical measures and their influences are illustrated in Diagram A by green boxes. At this stage the second-best "optimal" welfare change with respect to the reference scenario should be computed, considering also – as far as the needed detailed data are available – the equity and social inclusion implications of the optimal package;

- perform a sensitivity analysis to assess the impacts on welfare of a range of measures by taking them out of the policy package one at a time. At this stage it will be possible to determine if the "additional" welfare gain due to each policy instrument was greater than the welfare gain of using it in isolation. Priority should be given to the policy instruments of the optimal package which are hindered by one or more barriers, in order to understand what is the specific welfare loss due to the barrier, and compare it with the cost of removal. If the difference is positive, i.e. the welfare loss is greater than the cost of removal, the analysis of the policy package should be extended to include the measures needed to remove the barriers. Broadly speaking, specific measures to reduce the financial burden of some policy instruments (such as use of road pricing revenues to finance investments in new PT services) and/or to enhance the public acceptability (e.g. information campaigns and public engagement schemes) will enter into the policy package at this stage;

[7] As pointed out in TRANSPLUS 2003, to remove barriers it is useful to know that there are: i) contingent barriers which may be amenable to change through a direct action of the decision makers at the local level (politicians, city officers); ii) barriers that may be removed only by finding an agreement with other jurisdictions (e.g. in association with surrounding municipalities) or with higher level of governments; iii) embedded barriers which are not amenable to change – at least on short-term horizons – because they are intertwined with a particular location or scheme. Such embedded barriers may include physical and resource barriers, social and cultural barriers.

[8] Second-best optimality means that the instruments are set optimally given the constraints that apply on these instruments (SPECTRUM D4, page 3). In practice, we propose to identify in WP9 case studies the embedded barriers as the constraints which oblige to aim to second-best optimal packages

- finally, determine the "best feasible policy package", including those measures of the optimal package that were not subject to restrictions or for whom the barriers will be removed. This package will include also the related cost reducing instruments (e.g. recycling of revenue), public acceptability enhancing instruments or other measures needed to remove the barriers. The welfare change of this feasible package can be computed, and compared with the benchmark provided by the second-best optimal package without restrictions and ancillary barrier removing measures, in order to determine its relative efficiency.

Following the approach illustrated above, the analysis of packages of urban transport instruments should be able to highlight the effects in the single urban case studies of:

- those regulatory and physical measures mainly affecting the single transport volume components (separately for private car and public transport): number of users with access to a transport service/mode, average number of trips, average trip length, vehicle occupancy rate;

- the regulatory measures that affect the public transport producers running costs, e.g. specific environmental and safety regulations, and similar regulations influencing the private car user and/or producers costs. Any evidence of the influence of these regulations on the environmental costs and safety risks should be also considered;

- the regulatory and physical measures that have an influence on other components of the generalised price, such as travel time (separately for private car and public transport);

- the economic measures, including charges, taxes or subsidies whose effect is to alter the price paid by the transport users;

- finally, long-term physical measures (road capacity expansion, PT infrastructure improvement) which change the capacity and durability of the transport infrastructure.

The reference framework for the analysis of urban case studies discussed above is illustrated in Diagram A at the end of this section using as far as possible self-explanatory notations. The symbols used for the generalised price equations and the welfare components have been introduced in SPECTRUM Deliverable 4, and are recapitulated as follows:

N = numbers of consumers, identified in practice with the number of trips by mode (N1 = car; N2 = public transport);

CS = consumers surplus

p = producer price

CAP = total transport infrastructure capacity

D = durability of the transport infrastructure

v = value of travel time

T = time needed per unit of transport service

vT = unit time cost

h = monetary value of an accident for the transport user

R = accident risk

bR = unit accident cost

b = average government expenditure for an accident

bR = total accident cost paid by the government

REV = net revenue of government

$(1 + \lambda)$ = marginal welfare cost to society of raising a unit of tax revenue

t = transport taxes (note that subsidies may be considered as negative transport taxes)

The diagram is intended to show in greater detail how *regulatory and physical measures (green boxes)* may affect the various components of the systems and, through the pathways depicted by the arrows, how they enter in a direct or indirect interaction with the *economic measures (yellow box)*, whose effectiveness, and how this may be enhanced through packaging with complementary measures, is the central concern of SPECTRUM (as indicated by using a different colour for the economic measures box).

In the methodology presented so far we have not considered an important dimension: the geography of the city and the surrounding region. The “urban” policy packages have been discussed as the city was an unique homogenous entity, which is a simplification clearly far from reality.

Indeed, the circumstances that affect transport demand and the final outcomes of the policy packages can vary a lot within a city, between the core neighbourhoods where the density of attractive activities – shops, offices, entertainment, education, other services etc. – is higher and the peripheral districts, where usually residential dwellings predominate. This depends from the urban form and social context, with a range of situations which goes from:

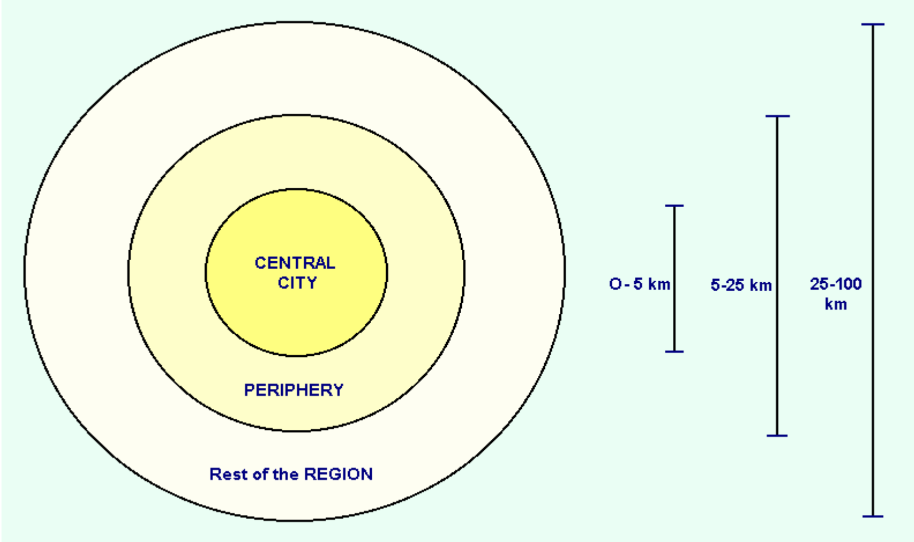
- the compact monocentric city where the great majority of employment and attractions is concentrated in the inner core, and population is spreading in the suburbs causing increasing commuter flows (both in absolute number and average distance) from the suburbs and even the surrounding rural areas towards the central city;

- the polycentric city, where both population and employment are distributed in several urban poles within the urban areas or in the wider urban region, and these poles are interconnected in a network by a road and/or rail transport infrastructure;

- the sparse city, where the population and employment centres (office complexes, etc.) spread in the peri-urban and rural suburbs of the city, causing an increasing share of suburbs-to-suburbs tangential commuter flows, mostly car dependent.

A schematic way of representing the variety of the urban territorial contexts is to consider two possible levels of spatial detail of data:

- **Core-periphery patterns (aggregate spatial representation)**: the city territorial context is subdivided in three concentric rings – the central city, the periphery and the rest of the region – as illustrated below:



- **District patterns (disaggregated cellular representation)**: the city territorial context is subdivided in a tiling of cells built around a first cell – the central city – adding a first layer of 8 surrounding cells which represent the Peripheries in the clockwise directions North, North-East, East, South-East, South, South-West, West, North-West, and then a second layer of 16 cells surrounding the first layer in all geographical directions, which represent the Rest of the Region, as illustrated below

RR N-W	RR North	RR North	RR North	RR N-E
RR West	P N-W	P North	P N-E	RR East
RR West	P West	Central City	P East	RR East
RR West	P S-W	P South	P S-E	RR East
RR S-W	RR South	RR South	RR South	RR S-E

A relationships between the abstract subdivisions of the territory in concentric rings (aggregate representation) or in tiling of cells (disaggregated representation) and the concrete geographical subdivisions of each city can be established on a case by case basis. This system of spatial codification can help to compare across cities the results of the implementation of urban policy packages which are spatially differentiated within the cities and urban regions.

In this way, at least in principle, it could be possible to analyse the implementation over space of a policy package considering the different circumstances in the central city, the peripheral districts (first ring) and the more distant suburbs (second ring). For instance, a policy package aiming to restrict car use may be applied in one city only in the central area where employment is strongly concentrated, while in another city with the same monocentric pattern could have been applied also in some peripheral districts mainly residential. A consideration may be given also to the different level of public transport services available in the different cells of the city - the latter is usually higher in the central city and lower in the peripheral districts – and the interaction of this with the convenience to shift away from car use to PT as a consequence of a car restriction policy package, for people living or working in the different zones of the town.

A standard spatial disaggregation of data may be useful not only to show the effect in similar cities (e.g. both monocentric) of the same policy package modulated in a different way over space (e.g. a parking charge policy limited to the central city or widened to the peripheral districts), but also to show how exactly the same package (again, for instance, parking charges only in the central city) can produce different effects in two cities with a different urban form. For instance, the effect of parking charges may be more strong and lasting over time in a monocentric city than in a polycentric one, where car users can more easily change the destination of their trips to other areas of the city free of charge.

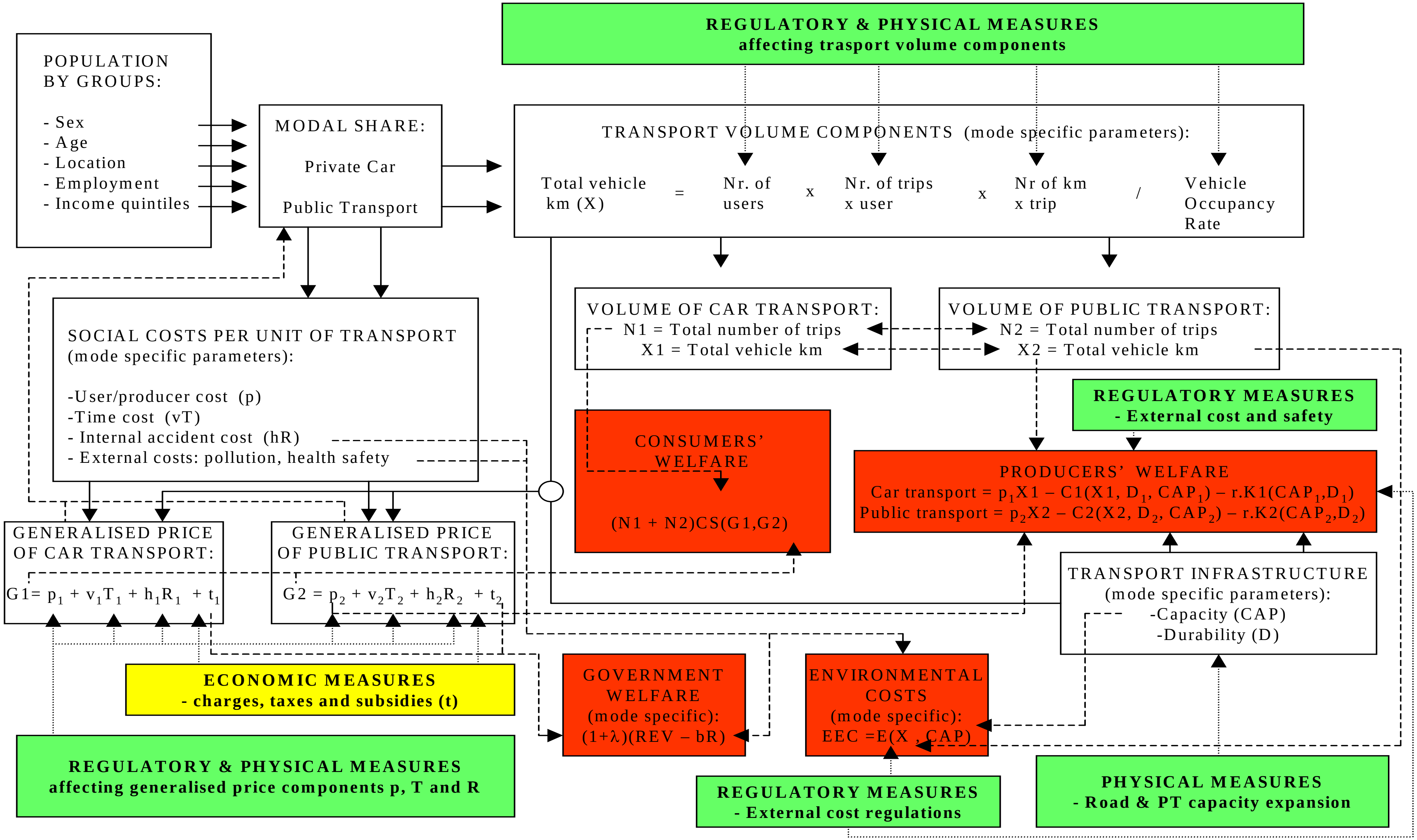
However, spatial disaggregation and analysis is not an easy matter. When the moment comes to apply the analysis to a definite area, at a lower scale, things begin to appear more and more complex – the smaller the level, the more complex the situation. The main issue here is the question of compatibility between different levels of analysis and action. In other words, a definite policy, aiming for sustainable transport at for instance a city area level, could be counter-productive at a regional level, and the same can be said for policies which are effective at the neighbourhood scale, but can have negative impacts at the city scale. For example, a policy aiming at a drastic reduction of congestion and local pollutant emissions within a definite urban area could lead to traffic and related pollution moving outside the perimeter. As a consequence, we have a better situation within the initial perimeter, but possibly degradation all around.
When dealing with urban transport issues, in particular, we shall consider that much traffic within a particular urban area is generated outside the area - either in other urban areas or in rural areas - and this is especially relevant for small urban areas. It follows that any tool for urban policy modelling/assessment is limited in usefulness if it assumes - explicitly or implicitly - that the urban area in question is a self-contained entity.

In concrete, the particular circumstances related to the urban form and spatial distribution of city users – residents, commuters, tourists – must be analysed on a case by case basis, using available data and the spatial disaggregation allowed by the existing city and regional models. The latter may be used to analyse the impacts of policies for different target populations and in different districts within the city or in the surrounding region. Comparison between cities could be done at more spatially aggregated levels, using the cellular representation or the concentric rings illustrated above to compare the results of model runs developed in the single cities.

The above considerations will be taken into account in the WP9 case studies, where different spatial impacts may be analysed depending on data availability. The present review of measures, with some notable exception (e.g. the theoretical discussion of spatial patterns of parking prices in section 8.1.3), do not include the spatial differentiation of the likely impacts of the measures, because any practical conclusion on this matter is strongly dependent from the singular circumstances of the cities, and can therefore more coherently be analysed in the context of the single WP9 case studies.

DIAGRAM A

SPECTRUM – Framework for the analysis of urban policy packages – Welfare impacts



3. Economic instruments

Economic instruments cause directly changes of prices for the consumers or changes in their incomes[9].

The three main objectives of economic instruments are:

- ✓ providing correct signals for the efficient and sustainable use of resources,
- ✓ the generation of the necessary revenues for the different levels of the government, and
- ✓ the achievement of a desired income distribution in a society.

Generally speaking, economic instruments can affect fixed or variable prices of relevance for travel behaviour, directly or though changes in location and land use. Examples of variable prices are public transport fares, fuel prices, parking charges and toll fees. Examples of fixed prices are registration fees and costs related to car ownership.

This section focuses only on a few of these instruments; road pricing, fuel and vehicle taxes, financial incentives for the production of clean vehicles and their use, and land taxation. Other economic instruments are covered in this report, particularly in chapter 8 related to parking measures and chapter 9 related to public transport measures. See SPECTRUM deliverable 5 (Outline Specification of a high level framework for transport instrument packages) for an extensive list of economic instruments.

Generally speaking, there is no perfect transport instrument and there are distortions in investment and pricing in the transport sector and other sectors of the economy. This explain why, from the theoretical point of view, we need to consider the interactions of several instruments.. In addition, the interactions of the instruments can be evaluated in the context of the high-level objectives: efficiency and equity. While pricing instruments can potentially increase efficiency, doing so might have adverse effects on equity objectives.

To identify the way instruments interact, i.e., to show synergies, additivity or substitutability with a particular instrument that targets a particular mode (market), we will examine:

1. The interactions between instruments that target a particular mode. An example is road pricing that targets externalities associated with road transport. Other pricing, regulatory, physical and investment instruments that target road transport, such as parking instruments, gasoline price, investment in road infrastructure etc., will consequently interact to different degrees with road pricing.

2. The interactions between instruments that target alternative modes. An instrument that targets a particular mode has consequences for demand for other modes of transport. For instance, road pricing will affect demand for public transport. Consequently efficient pricing in road transport will have consequences for public transport and the instruments available to target this mode.

[9] this definition does not includes regulatory measures that may cause 2nd order changes of producers prices (e.g. emission standards)

3. The interactions between the instruments on the basis of their responses to the high-level objectives. While road pricing improves efficiency it might have adverse effect on equity objectives. Hence other instruments such as those related to the provision of public transport services can potentially reduce the adverse impacts with respect to equity objectives.

4. Synergies between instruments are sometimes used to address barriers to the introduction of an instrument, as illustrated in the literature on road pricing. Other instruments such as the increase in the level of public transport subsidies are often proposed to secure public support for road pricing.

The literature on the interactions of instruments rarely discusses the degree of “synergy”, “additivity”, and “substitutability” between the instruments. It is a common practice to use elasticity values for the quantification of the impacts of an instrument. A price elasticity of demand expresses the change in demand induced by a price change. The response to an increase in price depends on many contextual variables, e.g. the availability of alternatives, geographical factors, level of car ownership, the initial price levels, etc (see, Goodwin, 1992; Ramjerdi, et al 1997; Glaister and Graham, 2000). The response is usually reported in terms of short-, medium- and long-run elasticity values, short and long term being only loosely defined (with respect to either the time span or extent of the effect). While Button (1993) defines short run as less than 2 years, medium run as 2-15 years and long run as longer than 15 years, Dargay and Gately (1997) propose that short run impacts take place within a year and long run impacts take about 13 years.

Furthermore different types of data (aggregate or disaggregate, time series or cross-sectional, before and after study) and methodologies are used for the estimation of these elasticity values. The differences in the types of data and methodologies contribute to the variation in the reported elasticity values in the literature. Cross elasticity values show even more variation than the own elasticity values, partly due to the market shares in each study. Dargay and Gately (1997) and Goodwin, Dargay and Hanly (2003) suggest that short run elasticity values are usually about one-third to half of long run elasticity values.;. The explanation is that the ability to respond to a price changes increases over time. Consequently in the following sections we will only focus on the plausible ranges of elasticity values rather than an extensive review of these values. The review presented in this chapter is based on the review of literature as well as interviews with some authorities at the Norwegian Public roads Administration.

3.1 Road Pricing

3.1.1 General characteristics

Road pricing may take several forms:

- ✓ *Area licensing* means that a fee has to be paid to be allowed to drive inside a particular area at defined times.
- ✓ A *toll cordon* means that one has to pay to cross the cordon in one or both directions at defined times.
- ✓ *Kilometre based charging* means that one has to pay per kilometre driven inside a defined area at defined times, while

- ✓ *time based charging* means that the basis for the charge is the time spent driving inside the area.

The two latter forms require advanced technology, while the former do not.

The high-level objective of road pricing is to increase economic efficiency. Road pricing achieves this through internalisation of the externalities of congestion and local pollution. Furthermore, road pricing also creates a traffic situation where some of the infrastructure investment projects that would otherwise be deemed socially profitable will no longer pass the cost-benefit criterion, thus saving money on the investment budget and redirecting investment to other projects, which will now appear more profitable. In this way road pricing contributes not only to static economic efficiency, but also to a more efficient long-term development path.

From a theoretical perspective, so-called *first best* road pricing, i.e. charging on each link of the road network according to the marginal social cost of traversing it with a particular type of vehicle at a particular point in time, produces the highest achievable economic efficiency in the transport system under the given conditions. No other combination of measures can outperform it.[10] This result can be derived in a variety of theoretical frameworks, from simple textbook economic models to complex network-based transport model systems. In the terminology of transport modelling, first-best road pricing is what is needed to achieve the system optimum in a situation where there is congestion and user equilibrium, i.e. an equilibrium where no-one has a reason to change their choice of route unless someone else does.

However, for technological and informational reasons, first-best road pricing is not feasible in practice. Only a subset of the links can be charged instead, and the charge cannot be based on real-time information about traffic conditions, but will have to be more predictable and stable (*second-best* road pricing).

Even so, past simulation exercises usually show large to very large efficiency gains from road pricing. Some form of road pricing seems to be the key ingredient in any combination of policies designed to increase the efficiency of urban transport systems. Indeed simulations very seldom show a package without road pricing to be able to outperform a package with road pricing included, even if that package only involves an imperfect and rough form of road pricing. Empirical experience from cities like Singapore and London seems to confirm this.

The theoretical work and the simulations almost always assume that travellers value time savings in the same way.[11] If this is not the case (and of course it is not), the simple concept of a unique marginal social cost of making a trip or traversing a link breaks down, and assessing the welfare gains of road pricing becomes technically more complex (Dial 1999) and requires stronger normative assumptions. In the end, we will probably want to have our efficiency calculations confirmed by public opinion, i.e., we will only be confident that road pricing actually increases welfare if it is also turns out to be a success with the public. The London experience is encouraging in this respect.

[10] Unless, that is, there are profitable investment opportunities. Also note that it is assumed that there are no distortionary taxation elsewhere in the economy and no restrictions on the instruments that can be used.
[11] See however for instance Small and Yan (2001), Eliasson (2001), Yang et al (2002).

Even if road pricing increases efficiency in the transport system, there is a concern that it will impact negatively on the efficiency of other parts of the economy, such as the labour market. So how well does road pricing contribute to economic efficiency in the wider context of the whole economy? A recent literature (van Dender 2002; Parry 2002; Mayeres and Proost 2001, 1997; Parry and Bento 2001; Mayeres 2001, 1999) confirms the need to take labour market impacts into account when setting road pricing charges and deciding on the use of the revenue. Charges must be set to internalise the congestion externality while avoiding, as far as possible, the negative impacts on labour supply. It turns out that the best way of doing this is to use the revenue to cut back distortionary labour taxes. Other uses of the revenue, like earmarking it for local public transport or returning it to the travellers through lump-sum transfers, seem to bring much smaller or even negative efficiency gains for the economy as a whole.

From the economy-wide perspective, then, road pricing should not be assessed in isolation, but only in combination with its inevitable other side, the use of the revenue. Potentially, there will still be very large efficiency gains, but now they are wholly dependent on how the revenue is used. Efficiency may or may not be the objective of revenue recycling. If it is, the potential efficiency gains for the economy as a whole from road pricing plus efficiency-enhancing uses of the revenue will be as large or larger than the isolated efficiency gains in transport.[12]

3.1.2 Implementation actors and processes

Implementation requires a legal basis and thus involvement of the national government is necessary. Otherwise, it is a wholly local instrument. Presumably some form of understanding with the adjacent local jurisdictions and a commitment with respect to the level of the charge and the uses of the revenue will be necessary to gather support for the measure from the public and adjacent jurisdictions. It is important that this political process still enables adjustments and improvements to the scheme as experience accumulates and as technology develops.

However, not all national governments have provided the legal basis for road pricing. Recent Norwegian experience shows that it is important that the conditions under which road pricing is allowed should be no less favourable to the local authorities than other, competing arrangements with respect to the amount of funds that are transferred from the national government. At the local level, the broadest possible political alliance should be sought to provide stable and predictable conditions for implementation.

The optimal level of the charge is dependent on the income level because the effect on demand of a certain charge is greater the lower the level of income. The optimal level of the charge is of course also dependent on the traffic situation, which in turn may depend on such factors are car ownership rates and the availability of public transport as an alternative. The location of the toll ring or the tolling points are important for the results and should not be decided by pure judgement but by an analytical procedure (May et al 2002).

The *cost of collection* depends on the technology chosen and the city configuration. For low optimal charges, the cost of collection may be an important factor for the assessment of the efficiency gains. While fuel taxes have practically no transaction cost, the transaction cost associated with other road pricing measures is between 10-40% of the revenues. Thus road

[12] The issue of revenue recycling has been extensively discussed in SPECTRUM D4

pricing may be supposed to be implemented first in large and heavily congested cities. The example of the Norwegian cities, however, shows that this is not necessarily true. The example shows that the need to finance infrastructure improvements is just as important as the need to reduce congestion when a city decides to implement road pricing. Provided some thought is given to how to combine the two objectives, financing infrastructure by user charges can also serve to improve the efficiency of the transport system in the short run.

3.1.3 Likely impacts

Impacts of road pricing on efficiency were treated in section 3.1.1. This section addresses other impacts of the instrument. A main effect of road pricing is the transfer of large sums of money from travellers to government coffers. Model tests indicate that the revenue from first or second-best road pricing schemes in different cities is from 1 to 2 times the size of the net benefit of the scheme (Ramjerdi 1992, Eliasson and Lundberg 2002) or an even greater multiple (Fridstrøm et al 2000). Further distributional effects are induced by the use of this money on the part of the government. As already pointed out, the total impact may be positive from the point of view of efficiency, but this depends on the use of the revenue. The main and induced distributional effects also have immediate implications for the attainment of other objectives, and in particular financial and equity objectives.

Concerning the *financial implications*, local governments are often severely constrained in their ability to finance better public transport services and necessary improvements of the transport infrastructure. Thus, raising revenue is an important ancillary reason for introducing road pricing, although this is not the principal objective of the instrument. Indeed, as we will explain below, only in case of very socially profitable projects and extremely severe constraints on other forms of finance should the scheme be designed with fund raising as the prime objective.

If we assume that the fundamental aim of using the revenue from road pricing to finance, for instance, public transport investments, is to achieve an higher economic efficiency of that mode, we may assume there exists a list of infrastructure projects with high benefit/cost ratios or plans to operate public transport in a more economically efficient way. Now, if these projects and plans have cost-benefit ratios that do not exceed one plus the shadow price of public funds[13] they should not be carried out, even if other and cheaper forms of finance are available (these should be used in this case to cut back distortionary taxes). However, if their cost-benefit ratios exceed one plus the shadow price of public funds, the projects should be carried out, but not necessarily by the use of distortionary tax money. Cheaper forms of finance from the point of view of society should be used instead.

Indeed, up to a certain level of the charge, road pricing will provide such cheap finance, as it improves efficiency in the transport markets without creating serious inefficiency in the labour market. Beyond this point, road pricing should not be used for financing, and the missing finance (if any) should be taken from other taxation instead. Thus the optimal way to finance efficiency-enhancing infrastructure projects and public transport plans when there is congestion on the roads will often be a mix of user charges and tax financing (Ramjerdi 1995).

The proportions in the mix will depend on the level of congestion, the elasticity of travel by car in the congested area with respect to the road pricing charge, and the shadow price of

[13] i.e., the cost to society of financing them through distortionary taxation

public funds. If the charging points must be placed such that traffic diverts easily on to other, perhaps even more congestible parts of the network, the optimal charge from an efficiency point of view will be zero or very low, and the infrastructure will have to be predominantly financed by taxes. It would however be equally wrong to place the charging points and set the charges to maximise revenue, since this may involve charging traffic with no or negligible external effects, and generally using charges that exceed marginal social cost. In general, the charging area and the charge should be set so as to optimally combine the need to internalise the external costs and the need for finance.

Concerning the *equity implications* of road pricing, reasons for the reluctance and widespread opposition to road pricing are surveyed in Eliasson and Lundberg (2002). Concerns about the distributional impacts are prominent on this list. Equity reasons for opposition to the Norwegian toll rings are analysed in Langmyhr (1997).

The equity concerns merit close attention – not just to facilitate implementation of a measure that can improve the efficiency of the transport system, but because equity objectives are important social objectives in their own right. It might be even argued that analyses of equity impacts are more important to road pricing decisions than to decisions about infrastructure building, because:

- ✓ first, infrastructure building is an ongoing process where those that did not get their new road this year might be the winners next year. Road pricing is different in this respect. It is a permanent redesign of the whole transport system, with no chances of the losers ever getting compensated by a reverse pricing policy next year;
- ✓ second, road pricing only achieves its efficiency objective through comparatively large transfers of money from individuals to the government. As a rule, motorists as a group stand to lose before recycling of the revenue;
- ✓ third, since government is the winner by far before the use or recycling of the revenue, the equity impacts depend very much on how the revenue is used. As we saw, revenue recycling to promote economic efficiency probably means to use it to cut the marginal tax on labour, whereas equity objectives will probably require quite other uses of the revenue. Thus there will be an acute conflict between the two objectives in the case of road pricing (Fridstrøm et al 2000, Mayeres et al 2003). This conflict is less pronounced in the case of infrastructure investment.

3.1.4 Interactions with other measures

Road pricing interacts with other pricing instruments, infrastructure provision and restrictions. The main interactions may be described as follows:

- ➩ <u>Interactions with other transport pricing measures (fuel taxes, parking charges)</u>: if road pricing is used in conjunction with fuel taxes, the optimal combination will be to use the fuel tax to internalise the externalities that are independent of context, such as CO2-emissions and road wear and tear, while (second best) road pricing takes care of congestion and local pollution. Unless road pricing is perfect, any one of these instruments would produce a less perfect result from the point of view of efficiency. The same goes for parking charges and road pricing: parking charges would only be able to internalise the externalities on the road in an imperfect way, while road pricing is an imperfect instrument to handle congestion in parking areas. More generally, there is a need for many different pricing instruments to be used together as long as there are externalities of different kinds and in different places.

- Interactions with car taxes: it is sometimes argued that car taxes should be shifted from ownership to use, since it is the use of the car that creates the external effects. The use of the car should certainly be priced so as to make the user internalise the costs that are imposed on others, but it is by no means certain that this should be accompanied by a reduction in car taxes. Other, more distortionary taxes should be reduced instead. In fact, from the point of view of financing government expenditure in an efficient way, the car is a very good object of taxation, precisely because so many feel that they cannot do without it (Ramsey pricing). From the point of view of equity, however, the car tax may be seen as unfair, taxing the less well off car-owners just as heavily as the rich.

- Interactions with public transport fares: in the absence of road pricing, public transport fares may be set at a low level as a second-best solution to congestion problems. Apart from being an imperfect instrument to tackle road congestion, this solution also creates distortions in the rest of the economy, since it requires a higher level of distortionary taxation to finance the public transport subsidy and the missing road pricing revenue.

- Interactions with infrastructure provision: road pricing is in general not dependent on other instrument to be effective, but may be combined with other instruments to overcome particular barriers to implementation, in particular supplying up to a certain level a cheap and abundant source of finance (as discussed in section 3.1.3 above). Because of this effect, road pricing and road infrastructure provision becomes *complementary* measures in attaining the efficiency objective, road pricing helping to finance infrastructure, and, as noted in May (2003) and elsewhere, infrastructure provision providing a way of making road pricing more acceptable to the public. But there is also a degree of *substitutability*, as road pricing makes the need for road investment less acute and changes the composition of the best road investment plan. Indeed, road pricing and some road investment complement each other with respect to the efficiency objective, while road pricing makes other road investment plans superfluous. Again, equity considerations tend towards the opposite conclusion. In particular, it may be argued that precisely those that tend to lose from road pricing should be given something back in the form of better roads. A fair compromise might consist in using the revenue, or part of it, to invest in highly profitable road and public transport improvements.

- Interactions with car restriction measures: restrictions might be used as imperfect substitutes for road pricing. The problem with restrictions (number plate restrictions, car-free city centres) as compared to road pricing is that they affect all trips, not only the trips for which there is a low willingness-to-pay. Thus restrictions are a less efficient means to achieve the same end as road pricing. However, Daganzo (1995) shows how road pricing can be combined with restrictions to produce Pareto-efficient outcomes, i.e., outcomes were every car commuter in the local community stands to win. Such strategies need not be better in terms of economic efficiency than a pure pricing strategy. Their merit is rather that they achieve a more modest efficiency gain while meeting a particular equity objective, namely to avoid dissipating the benefits. The winners from pure road pricing with recycling will often be taxpayers outside the city or local public transport users. Daganzo’s scheme keeps the gain within the community of local car users.

- Interactions with land use: the land use effects of road pricing are generally considered to be small. Simulation exercises seem to confirm this (Eliasson and Mattsson 2001).

It is often argued that improving the public transport system is a necessary complementary measure to road pricing as it provides those that are priced off the road with a good alternative. In doing so, it makes road pricing more efficient as an instrument to influence demand, or put otherwise, it makes the optimal charge lower. A side effect of this is that the more is invested in the public transport system, the less is the ability of road pricing to finance the investment. The same goes for road investment: The more of it before road pricing is introduced, the lower the optimal charge.

However, little is known on the timing of the investment and pricing instruments.[14] Judging the timing on purely efficiency grounds, there is something to be said for introducing the most efficient instrument (road pricing) first, and let the resulting situation decide which of the infrastructure projects will be needed. Compared to the opposite order, this will give less road projects and more public transport projects. Anticipating this, if finance is not severely constrained, we might after all move public transport projects forward to make road pricing more efficient.

3.2 Fuel and vehicle taxes

3.2.1 General characteristics

Fuel taxes are levied on the purchase of fuel. It was originally introduced for generating revenues for investments in road infrastructure. This instrument is now applied both for generating revenue and for addressing car related externalities. Fuel taxes can be differentiated by type of fuel in order to create incentives for the users to switch to cleaner fuels and eventually to more fuel-efficient vehicles. The higher tax levied on leaded fuel is an example.

The high-level objectives of fuel taxes are to generate revenue and to increase economic efficiency. Intergenerational equity is achieved through internalisation of externalities of CO2 emissions. Economic efficiency is achieved through reductions of regional and local emissions of pollutants and to some extent by having impact on congestion. Fuel tax can also contribute to the internalisation of externalities associated with accidents. Since fuel taxes are connected to car use they are more suitable for internalisation of accident and environmental externalities than general taxes or vehicle taxes, but they are less accurate than weight-, distance and time differentiated fees.

There has been substantial increase in fuel economy since 1975, with significant consequences for the fuel tax to meet its financial objectives (see for example Wacks, 2003: Ang-Olson Wachs and Taylor, 2000). Already a number of alternative instruments (such as road pricing and the use of GPS) have been proposed to complement fuel taxes in order to meet the financial objectives.

Vehicle taxes refer to those levied on the purchase of vehicles and annual fees. Vehicle taxes serve two purposes, for generation of revenue and to promote a desired fleet of car with

[14] Some remarks can be found in May (2003). On the implementation path of road pricing, see the MC-ICAM project, in particular the paper by Verhoef et al at: http://www.imprint-eu.org/public/Papers/IMPRINT4_ver-hoef2.pdf.

respect to size and environmental and safety objectives. Vehicle taxes are differentiated by the engine size, etc, in order to create incentives for the purchase of more fuel-efficient vehicles. The high-level objectives of vehicle taxes are to generate revenue, to decrease car ownership and to promote a fuel-efficient car fleet.

3.2.2 Implementation actors and processes

Fuel and vehicle taxes are generally applied at a national or regional level. There are a few examples where a fuel tax is applied locally to generate additional funds for transport infrastructure, such as the case of Tromsø in Norway (see Milne, Niskanen and Verhoef, 2000). Substantial fuel tax differences between regions can lead to cross-border fuelling and additional total kilometres driven with car (Rietveld, et al 2001).

Since fuel and vehicle taxes are indirect taxes, there is no institutional obstacle to the change of policies related to these taxes, except for public opinion, which can be an important barrier. The responsibility for planning and implementation of the policies related to these instruments lies at the national level. All national governments have a legal basis for fuel and vehicle taxes in place. Assuming the means to collect indirect taxes are in place, there are no specific technological requirements for the implementation of these instruments.

The levels of the fuel taxes are related to the objectives of this instrument with respect to revenue generating and economic efficiency. Nevertheless equity considerations often play a role in the decision about the level of these taxes. The structural factors (factors exogenous to the transport policy context such as topography, climate, city configuration, population density, income level, etc.) play a minor role in the design of this instrument. An exception is the level of income. Since these taxes are normally levied at a national level the disparities between urban and rural areas plays a major role in the level of fuel taxes. The level of vehicle taxes is also determined by the objectives of this instrument, which are raising revenue and increasing the fuel-efficiency of the car fleet. These taxes are levied at a national level and hence structural factors play minor role in the level of these taxes, except for income.

3.2.3 Likely impacts

In general an increase in **fuel tax** will decrease car-use, in terms of kilometre and number of trips, increase the use of alternative modes of travel, decrease fuel consumption, decrease in emission of pollutants and to some extent congestion, improves fuel efficiency, increase car occupancy and a more fuel efficient car fleet. The impacts are not uniform over all travel purposes, and usually larger for discretionary trips (e.g. shopping). An objection to the further increase in fuel efficiency in the transport sector is based on the costs especially compared with other sectors. Higher fuel taxes would increase fuel efficiency in the transport sector. However, since fuel prices in the transport sector are relatively high compared to the other sectors, the transport sector has already done major efforts to increase fuel efficiency.

There is a difference between fuel consumption and traffic volume. In the short-run these are highly correlated. The correlation decreases over time since it is possible to switch to more fuel-efficient vehicles. This is the explanation for similar short run price elasticity of fuel consumption and traffic volume. Traffic volume is usually measured by vehicle kilometres. In the long run price elasticity of fuel consumption tends to be larger than the price elasticity value of traffic volume. There may be even a difference in the short run price elasticity, since it is possible to adopt a less fuel consuming driving style as a response to higher fuel prices.

However, fuel taxes do not constitute a large part of the variable cost of driving. Consequently the reported demand responses to increase fuel taxes are small, at least in the short run. Different studies have focused on comparative values of elasticity. Some examples of this type of literature are Goodwin (1988, 1992), Oum et al (1992), Harlow Fox (1993), Glaister and Graham (2000) and Litman (2004). The studies that have relied on price elasticity values from the US have reported lower values. A short run elasticity value of fuel demand with respect to fuel price of –0.2 to –0.3 and the long-run elasticity value is –0.6 to -0.8 seem to coincide with most recommendations on the range for Europe. The long run price elasticity of traffic volume is in the range of -.35 to –0.6. The price elasticity values of traffic volumes vary among travel purposes. Commuting and business travel are less sensitive to price changes than discretionary travel purposes (see for example Fox, 1993). Tanner (1981) cited by European Commission (1996) estimates a value of –0.31 for (long run) car-ownership demand elasticity with respect to fuel price.

Long run impacts of fuel taxes can be related to the changes of destination and eventually changes in home and work locations.

Increases in **vehicle taxes** (taxes on purchase of new or second hand vehicles and annual fees) may lead to the decrease in car ownership. However, as vehicle taxes are part of the fixed costs, an increase in these taxes might result also in an increase in car-use, once these costs are paid for. The overall result is a decrease in car use, increase in environmental quality and shifts in modes of transport. Vehicle taxes that are linked to the size of engine or fuel consumption contribute to an increase in fuel efficiency of the car fleet. High vehicle taxes might encourage the average age of the car fleet to increase, with inefficiently high levels of maintenance and repair costs or negative consequences for emission of pollutants and safety. The short-run effects of vehicle taxes are usually small, however over time the impacts can be significant. The elasticity of vehicle ownership with respect to price is estimated to be -0.4 to -1.0 (Litman, 2004). This coincides with earlier estimates (Tanner, 1981: Harbour, 1987).

Different studies suggest that reductions in vehicle taxes (purchase and annual fees) accompanied by increases in fuel taxes potentially contribute to the highest gain in welfare (see for example Kavalec and Woods, 1999). These studies do not address the impacts of the different taxes on the whole economy. In this sense they are partial in nature and do not take into account the possibility to reduce distortionary labour taxes instead.

3.2.4 Interactions with other instruments

Fuel taxes are generally accompanied by different regulatory measures related to fuel efficiency and level of pollutants. A good example is related to leaded fuel. The substantial decrease in the consumption of leaded fuel was the result of both regulatory and pricing measures. Rationing, another regulatory measure, has been used in Singapore to control the age and the size of the fleet of car (KONSULT, 2004).

While regulatory measures on emissions and fuel efficiency have important impacts on the reduction of emission of pollutants from road transport, they do not have any impact on the total vehicle kilometres and the level of congestion. The study by Proost and Dender (2001) illustrates this point. According to this and other studies conducted in the Auto Oil II

Programme of the European Commission, using the TREMOVE model[15], we can conclude that urban areas with significant congestion problems are benefiting more from a significant fuel tax increase than an equivalent fuel efficiency standard, as the fuel tax will induce stronger incentives to reduce car use. As a result the costs of accidents, noise, pollution and most importantly congestion are significantly reduced. It has been noted that at the high fuel tax level in the EU a significant fuel tax increase will drive consumers to extra investments in new technologies reducing fuel consumption. This is cost-inefficient as in most cases the saved fuel costs and external costs do not compensate the additional costs of these technologies. Road pricing may avoid these inefficiencies while remaining effective in CO_2 emission abatement.

Some studies have focused on the interactions between economic instruments that can be applied to car ownership (vehicle taxes and annual fees) and fuel taxes. Example of these studies are Tanishita et al (2003) and Ramjerdi et al (1996). Both studies show that fuel taxes are more efficient of vehicle taxes in terms of total welfare effects.

Fuel taxes are in general a good measure of road use, however they will not address congestion externalities in the same was as it is possible through road pricing instruments. Different theoretical models have been developed and applied for the evaluation of the interactions of fuel taxes with other pricing instruments. Mayeres (2000) uses a general equilibrium model to study the interactions of three instruments, fuel taxes, road pricing and subsidies to public transport in Belgium. The results reported from this study show that peak road pricing is a more efficient instrument for tackling congestion while fuel taxes are more efficient instruments for reducing emission of pollutants and transport accidents. The overall performance of peak road pricing is better than fuel taxes in terms of efficiency. This study is discussed in SPECTRUM Deliverable 4. Tanishita et al (2003) suggests that increase in public transport subsidies can be efficient (in another context, in Japan).

With increases in fuel taxes one can expect shifts in the mode of transport, slow (walk and cycle) modes and public transport. While these are numerous reports on the cross-elasticity values of demand for public transport with respect to fuel prices (see previous references on elasticity values), the reported cross-elasticity values have much more variation and are significantly lower than own price elasticity value of fuel prices. There are different explanations for this large variation. With an increase in the fuel price some of the trips will not necessarily switched to other modes, but will not be made at all or one might continue to use a car, but to a different destination that is closer. Another explanation is that a cross-elasticity value depends on the initial market share. However, although the evidence of the cross-impact on public transport demand may be weak in some cases, increase of fuel prices should be accompanied by improvements in the services of alternative modes, also to offset any adverse effects on equity objectives.

[15] TREMOVE is a model based on TRENEN that, unlike TRENEN, includes modules that enable to calculate the composition of the vehicle stock, fuel composition and emissions per pollutant in detail. TREMOVE has been developed during the Auto-Oil II Programme.

3.3 Financial incentives to the production and purchase of clean fuel vehicles

3.3.1 General characteristics

The transport sector is heavily dependent on fossil fuel. The motivation for clean fuel vehicle technologies has been related to energy security and air quality and climate change. The variety of clean technologies fuels include synthetic diesel and gasoline, compressed natural gas (CNG), methanol, ethanol, biofuels, battery electric, hydrogen fuel cell and hybrids. There has been a significant increase in fuel efficiency in gasoline driven vehicles, even though the entry of larger and more powerful cars in the market have counteracted some of the gained efficiencies. Some of the alternative fuel technologies are already available in the market. An example is hybrid electric vehicles that combine the internal combustion engine of a conventional vehicle with the technologies in an electric vehicle with significant improvements in fuel economy (twice that of conventional vehicles). Generally speaking, a hybrid vehicle offers extended range, a shortcoming among some of the alternative fuel vehicles. Some other technologies require considerable improvements to bring the costs down, such as hydrogen fuel cell technologies. These technologies should be evaluated on their lifecycle reduction of emissions of greenhouse gases and other pollutants.

Clean fuel technologies contribute to high-level objectives related to the reductions of CO2 emission (inter-generational equity), reduction of emission of other pollutants and energy goal.

Different economic instruments can create incentives to production and purchase of clean fuel vehicles. The scope of these instruments covers public support for financing research, development and demonstration programmes, production subsidies, financial support for dedicated infrastructure to differentiated taxes on fuel and vehicles. Another widespread economic instrument to promote purchase of alternative fuel vehicles is differentiated taxes on vehicles and fuels.

Hydrogen and fuel cell technologies could form an integral part of future sustainable energy systems. Both the EU and the US have launched extensive programmes for more research, larger demonstration and deployment projects, and regulations and standards appropriate to the future hydrogen economy. Other technologies have been supported through governments support for research, demonstration and deployment projects and production subsidies. The market for a new technology is subject to network externalities, in the sense that the launch and growth of the market requires an initial size (often referred to as a critical mass). This has induced different levels of the government to invest in a particular fleet of alternative vehicles. This policy has been pursued extensively in Europe and in the US.

Indeed, structural factors such as topography, climate, city configurations and population density are expected to influence the diffusion of specific technologies. A product requires a sufficient growth in its market size to stay viable. Some alternative fuel vehicles are “city cars”. They are small and light and not equipped with powerful engines. These factors make them more or less suitable for different environments. Another important variable is the distance between refuelling stations and the range of the alternative fuel car (the distance that can be covered when fully fuelled/charged). Since alternative fuel cars that are small are not suitable for driving on intercity highways, they cannot fulfil all the different demands of a household on a car (multi purpose). Consequently they are suitable as a second car in a household (Ramjerdi and Rand 1996) and probably not very suitable for rural areas.

3.3.2 Implementation actors and processes

Responsibility for planning and implementation of clean fuel instruments lies at different levels, from national to local authorities. Differentiations of fuel and vehicle taxes are usually the responsibility of the national governments. Others financial incentives such as reduced toll or parking fees are local. Many alternative fuels require dedicated infrastructure, such as refuelling stations. Financial support for the provision of the necessary infrastructure can be local or national. Provision of information on the location of refuelling stations for alternative fuels can be supported locally or nationally.

Clean vehicle technologies rely on vehicle design changes (with respect to weight, size, and power of the engine) that might require institutional and legal reforms.

3.3.3 Likely impacts

The impacts and the contributions of the financial incentives to production and purchase of clean fuel vehicles are mainly through reduction of emissions of pollutants and CO2 from transport. There are some exceptions. The contribution of clean fuel technologies to the reduction of particulates is not substantial.
The impact and the contribution of different technologies vary significantly. The following table provides a comparison of some of these technologies.

Table1: Alternative Fuels Compared (Pilorusso Research, 1995; Alternative Fuels Data Center; USDOT, 2003).

Fuel	CO_2*	Advantages	Disadvantages
Diesel	20%	Widely available and used. Reduces carbon emissions.	Increases emissions of particulates, sulfur and noise.
LPG	10%	Increased efficiency and reduced emissions.	Requires rebuilding engines. Limited availability.
CNG	20%	Increased efficiency and reduced emissions.	Requires rebuilding engines. Limited availability. May reduce methane.
Methanol	60%	Reduces some emissions.	Poisonous. Increases some emissions.
Ethanol	0-60%	Reduces some emissions.	Increases some emissions. Energy savings depend on fuel source.
Electricity	20-70%	No tailpipe emissions. May be generated from renewable sources.	Reduced vehicle performance. Vehicles are currently expensive. Energy savings depend on how electricity is generated.
Hydrogen	20-70%	No tailpipe pollutants.	Not currently available. Energy savings depend on how hydrogen is produced.

* Estimated reduction in lifecycle CO_2 emissions per vehicle-mile compared with gasoline.
Source: Litman, 2004

A study by Nakata (2000) shows that hybrid vehicles could make significant contributions to the reduction of CO2 emission in Japan in the long run (2040). The study is based on a partial equilibrium model that accounts for technological changes in response to policy instruments such as fuel taxes.
Some of the clean fuel technologies require smaller and lighter vehicles, which could have adverse effect on traffic safety.

3.3.4 Interactions with other instruments

In their study, Difiglio and Fulton (2000) address the potentials of clean fuel technologies and fuel taxes in order to achieve the Kyoto target for the reduction of greenhouse gas emissions by 2010. They conclude that technology oriented policies can only achieve the target by 2030. To meet the target by 2010 requires large increase in fuel taxes accompanied by policies that promote fuel efficiency in vehicles. Some of the technologies such as the hydrogen fuel cell are not yet available in the market.

The increase in fuel efficiency usually implies a decrease in running costs of a vehicle and increase in car use together with an increase in the costs of other transport related externalities such as congestion, accident and noise. Meanwhile some of the gains related to decrease in the emission of pollutants would be lost due to the increase in total vehicle kilometres. Consequently financial instruments to purchase of clean vehicles should be accompanied by traffic management instruments (such as other pricing and regulatory measures). Proost and Dender (2001) address this subject in their study. Their calculation shows that congestion and unpaid parking are the main sources of inefficiencies in an urban area. Fuel efficiency instruments alone are not able to address these inefficiencies. Fuel efficiency measures accompanied by an increase in fuel taxes results in the greatest welfare.

3.4 Property taxation

3.4.1 General characteristics

The objective of property taxation – in as much as it is relevant to transport – is to help finance local infrastructure provision and maintenance.
As a start, we may make a distinction between two polar cases. In the first case, the property tax rate is uniform across the local or regional jurisdiction. Such taxes have historically played an important part in financing local transport infrastructure and services in many countries, as for instance the USA, the UK and the Netherlands. There are several problems with this form of finance. Often, the inhabitants that gain from the infrastructure improvements are those living in a particular area, while those who pay include a much wider group. This gives rise to arguments about the fairness of the tax. Furthermore, under the constraints imposed by legislation or public acceptance, revenue from the property tax will often not be able to finance more than a part of the necessary maintenance and investment (under-provision of public goods). In the last decades in particular, voters have tended to prefer tax cuts and ceilings on tax rates to public good provision.

There is also the problem of tax competition. Other things being equal, firms and households that are able to relocate freely or at little cost will tend to locate in the jurisdictions with the lowest local tax (while perhaps still making use of the same infrastructure as before). This forces all local jurisdictions to reduce taxes to a sub-optimal level.

The opposite case is a property tax aimed specifically at those who are most likely to gain from the infrastructure improvement. This is sometimes called value capture. The idea is that an increase in the accessibility or attractivity of an area in the end will be reflected in property values in that area. Taxing the properties whose value will increase with the particular infrastructure improvement will help finance the investment, and might very well constitute a Pareto improvement (an improvement where nobody stands to lose).

Evidence on value capture is summarised in May and Matthews (2001). To quote: “Value capture and business taxes are designed to reflect the windfall benefits to existing developments from improved accessibility. The simplest system is a tax related to turnover or number of employees, though the tax may also be related to land values and/or other transport service level criteria. In Vienna the "Dienstgeberabgabe" is a municipal tax collected from all employers in the municipality. Employers pay a fixed rate per employee and the tax revenue is earmarked for investment in the Vienna subway. In French cities with population greater than 20000, the "versement transport" is levied on employers who have more than nine employees and who do not provide workplace-related transport or housing facilities. The tax is calculated as a percentage of the company’s wage bill. This percentage varies according to the type of location (central/peripheral), the number of inhabitants and the type of public transport available in the city. Tax revenues are earmarked for subsidising public transport investment and operating costs. While such schemes provide a valuable source of finance, there is little evidence on their impacts on travel. True value capture, as proposed, involves taxing land owners close to new infrastructure to reflect their increased accessibility benefits. There is little evidence of its application in practice.”

Value capture as defined in May and Matthews is not necessarily a property tax, although their “true value capture” is. We would suggest that a tax on turnover like the Austrian “Dienstgeberabgabe” is much more akin to local sales taxes as found in the USA. The “versement transport” is a local labour tax earmarked for transport. Local wage taxes or income taxes are used by at least some local governments in 14 US states (Braid 2003).
Private or public transport operators may sometimes make use of the idea of value capture. Railway companies may buy land in the area where they plan to build a new line, and sell it with a profit to property developers when the plans to build the line are made public, thus helping to finance the construction of the line and securing a stable demand for the services. This is for instance still common practice in Japan.

Evidence from Norway, gathered as part of EU-funded FATIMA project, suggests that there are many informal ways to apply the same principle. Even if property taxes are not an important source of revenue for local authorities in Norway, local jurisdictions may negotiate contributions from developers or local firms as a precondition for implementing infrastructure plans that will benefit the firms or developers, or as a precondition for approving the private developers’ plans or plans for expansion or relocation put forward by the firms. Thus value capture is probably occurring in a variety of legal and institutional frameworks.

The same picture emerges from UK experience, where such negotiated or forced private contributions to financing infrastructure has been given the name “Developer contributions”. May and Matthews (2001) says: “Developer contributions towards the financing of transport infrastructure can be required from developers as part of the process of obtaining permission for development. This approach has been applied successfully in the UK to secure finance for new roads and also for the provision of park and ride sites. More recent examples are for developers to contribute to public transport serving new developments (e.g. at the Leith dockside in Edinburgh or Hounslow in west London (DoE/DoT 1995). In some cases, eg London Docklands, financial contributions may be voluntarily offered by the developer as a potential means of influencing the timing, scale, design or some other aspect of the scheme (Nash, Matthews, Granero and Marler, 2001). The main risks are that the developer may go elsewhere if too many contributions are demanded and that the social benefits of the scheme may be compromised if developers are permitted to influence it too much to their own benefit.”

A somewhat related form of finance is the tax increment financing (TIF), which is used in 46 states of the USA, according to a 1998 survey. In the USA, separate agencies such a school district and a city authority can each levy taxes on property for their own purpose. Suppose a transport infrastructure project is assumed to increase the tax base in an area around the investment. Then if this is a “blighted” area, TIF allows the increment in the school tax revenue in that area to be used for financing the transport project. Thus the total tax rate is supposed to be kept constant, but revenue is transferred from one authority to another, allowing improvements that increase the tax base to be financed. TIF has been studied in the public economics literature, in particular by Brueckner (2001) and Fernandez (2004).

3.4.2 Implementation actors and processes

Property taxation is widely used by city governments to finance transport spending, both in Europe and in the US. This will probably continue in the future. However, our survey (see below) has indicated that there are better alternatives. If a local tax must be used, it is probably better to use sales or even wages as the tax base.

However, developer contributions and “true value capture”, as May and Matthews call it, seems to be less studied and may very well have better properties. In the voluntary and freely negotiated cases of developer contributions, we may at least be reasonably sure that the combination of the transport improvement and the finance constitutes a Pareto improvement.

3.4.3 Likely impacts

Parry (2002) studies the efficiency costs of raising money for transport purposes by the use of a local income tax, property taxes, gasoline tax and transit fares in the case of Washington DC. By the efficiency cost of a particular tax instrument we mean the marginal cost to society of increasing this tax, taking into account its effects on the transport markets, the housing markets and the labour market. In a situation with optimal taxation, the efficiency cost of all instruments would be the same, but since the current tax system is certainly not optimal, small changes from the current situation will cost less for some instruments than for other. In particular, instruments that internalise some externality will tend to have a negative cost, although this is by no means certain if we take the impact on demand and supply on adjacent markets into account. As pointed out by these authors, the overall efficiency effects of policies can be very different from their partial equilibrium effects.

“To provide a flavour of the results”, says Parry[16], “under our central parameter assumptions the (long run) efficiency cost of raising an extra dollar of revenue from the labour tax is 23 cents; from higher transit fares is 20 cents; from property taxes is 1 cent; from gasoline taxes is – 3 cents; and from congestion charging is – 12 cents. Costs are higher under the labour tax because this policy reduces labour supply, and under the transit fare because this policy indirectly increases driving externalities. But, for several reasons, the efficiency case for raising the additional revenues from gasoline and congestion taxes is perhaps not quite as overwhelming as we might have thought.”

Judging from these results, we would not want to use property taxation to finance transport spending if road pricing is possible. It may be noted that the efficiency cost of the property tax would have been higher if there where no housing subsidies in Washington, and that the

[16] When interpreting Parry’s results it must be remembered that Washington DC is a very congested area, and that the current levels of the taxes there might be very different from the levels in European cities. Thus the results can at most give a rough indication of the relative efficiency of the taxes in European cities.

efficiency cost of the gasoline tax will probably be higher in Europe, since European gasoline taxes cover more of the external costs of driving. It may also be noted that increasing returns to scale in the provision of transit services was assumed, and this might be important for the results on the transit fare.

Other studies, such as Gong and Zou (2002) indicate that if the local government can choose between a property tax and a tax on consumption, the property tax should be set to zero (assuming it could not be negative) and the tax on consumption should be used. Thus the overall picture of the efficiency of the property tax (in the case of a uniform rate in the whole city) is not so bright. It seems that if there are other sources of finance (except for the labour tax and possibly the transit fare), they should be preferred.

However, this conclusion does not apply to value capture. In May and Matthews (2001), both developer contributions and value capture are assessed as contributing, although moderately, to economic efficiency. They are also seen as equitable and fairly acceptable, but apparently not contributing to economic growth.

Turning to the American TIF, Brueckner (2001) shows that without TIF, financing the improvement in the targeted area without a rise in the property tax rate is only possible if the public good (i.e. transport infrastructure) in that area is seriously underprovided. TIF may make it possible to finance the improvement in the targeted area without a rise in the tax rate in some additional cases, i.e. if the public good is moderately underprovided. However, even in the cases where TIF will work, it will not necessarily finance an optimal level of the public good.

Property taxes will impact also on *location decisions and on land use*. Braid (2002) provides a theoretical study of the spatial effects of business property taxes and local wage taxes. It is shown that if a central city increases its local wage tax or business property tax above the level of the suburbs, workplaces just inside the boundaries of the central city will tend to disappear, and residents in these places commute to employment concentrations that form just outside the boundary. It is also shown that given the choice, the central city authority should set the business property tax to zero and use only the local wage tax. Braid (2003) improves the model by including land as an input in production. This dampens the effect on the city boundary. There is a reduction in employment just inside the border, but not as drastic as before. Also, there is increased employment just outside the border, but less than before. The land use effects of the French "versement transport" can be judged from these studies. Braid (2003) also contains a short survey of alternative models.

3.4.4 Interactions with other measures

The surveyed literature suggests that land taxation as an instrument to raise money for local transport purposes and other forms of local taxation with the same purpose, including local transport taxes, will not complement each other if used together – rather, the most efficient tax should be used alone.

If land taxation is the preferred or only available option for financing transport improvements, it constitutes a complement to investment policies. To avoid any unwanted land use effects, regulatory land use measures might be added to the policy package.

4. Physical restrictions to car use

It is generally difficult to provide sufficient new road capacity in most urban areas, so attention is focused on the role and the use of existing road capacity. Moreover, reductions in road capacity for car use may seem reasonable to encourage the use of alternative modes. Physical restrictions can be distinguished into two groups:

1. road capacity for car use is reallocated by introduction or extension of bus lanes/priorities, cycle lanes or light rail systems. These measures generally aim not only to reduce car traffic volume but also to encourage the use of public transport or cycling and to provide a frequent, punctual and reliable service or a safe transport route.

2. road capacity for car use is reduced by changes or extension of a defined area/zone (often a city centre) into a pedestrian area or car-free area, the closure of a particular street entering a city centre, and introduction of traffic cells in which a city centre is divided into cells, where car traffic movement between each cell (or entering from outer areas) is prohibited or restricted, based on limited entrance points. Some types of vehicles like buses and service vehicles are usually exempted from these restrictions.

4.1 Reallocation of road space by introduction or expansion of dedicated lanes

Physical restrictions limiting car use in urban areas or other specific zones by reductions in road capacity may include – among others – bus lanes and priorities, cycle lanes, extensive pedestrian areas and low emission zones.

4.1.1 General characteristics

The primary objective of cycle lanes/routes physically separated from motorised traffic is to make it less dangerous to cycle and to reduce cycling traffic accidents. Many cyclists do not feel safe in traffic, especially when they are travelling in mixed traffic on roads with heavy car traffic. People’s subjective comprehension of insecurity influence their choice of transport mode. Secondary objective, especially for cycle routes defined as a comprehensive network, is to give current cyclists increased mobility and better access to their destinations and to increase cycling, i.e. to reduce the number of motor vehicle trips (KONSULT, 2003).

Bus lanes are a long established policy tool in transport planning, to give priority on a link to buses (and usually other modes such as emergency vehicles, cycles, and often taxis). They vary somewhat in terms of their characteristics, but all have strong similarities of:

- covering radial routes to or from city centres;
- with a length of between 1km and 10kms (in any radial direction);
- not being continuous lanes, but being designed to fit into an existing urban and road structure;
- being mixed with other physical measures (with a strong emphasis on links with junction priorities, changes to bus stops etc).

Experts suggest that bus lanes should preferably be concentrated on critical sections of the urban network, where more substantial time savings may be achieved, rather than widely spread across the city network (CAPTURE, 1999). Normally the bus lanes are with-flow lanes, but also contra-flow lanes have been introduced to prohibit cars on the lanes.

HOV lanes are very similar to bus lanes and are often combined with them (so the effects are not only related to car users, but also to public transport). Enforcement is an issue with HOV lanes as it is with bus lanes. However, it is more difficult to spot an infringing private car (with only one occupant as against two or more) than it is to spot a car in a bus lane.
High occupancy toll lanes (HOT) have been introduced to make better use of existing HOV lanes by opening them to paying customers as well. The aim is firstly to provide capacity more efficiently than either conventional HOV lanes or general-purpose lanes and secondly to charge congestion and thus collect revenues.

The general aim of zoning is to make movement of people more pleasant, and to slow down traffic speeds and reduce the amount of traffic. The kinds of arrangements covered in this broad area are either pedestrianised areas and streets or restricting vehicle types allowed in certain streets and areas.

An environmental zone is located mainly in the central part of the city, which is especially sensitive to pollution and noise from road traffic. In this area driving is only permitted for vehicles fulfilling certain environmental demands. Restrictions have mainly addressed heavy vehicles (LEDA, 2003).

A detailed description of different possible kinds of environmental zone systems can be found in the project TRENDSETTER (TRENDSETTER, 2002). The main types of such zones can be grouped as follows:

1. prohibited zone in relation to the age of the vehicle combined with a weight limit;
2. prohibited zone in relation to vehicles' loading capacity limits;
3. prohibited zone for vehicles with a weight (or length) over a special limit;
4. reduced accessibility for traffic;
5. access control to defined area during a special time of the day.

The main barriers of implementation of physical restrictions can be identified as follows (KONSULT, 2003; Urban mobility project, 2002):

- legal: there are no obvious legal barriers to the implementation of physical restrictions;
- finance: zones and dedicated lanes can be implemented relatively with low costs but additional (and costly) complementary systems (like traffic control or access control system) are sometimes also required;
- political: reduction of road capacity for general traffic is likely to give rise to protests from local car users, and at the same time to supports from PT/cycle users and local inhabitants;
- feasibility: the nature of the network and/or urban structure is the key feasibility issue.

The cost of physical restrictions depends on individual measures, but is usually cheaper than measures to increase road capacity (KONSULT, 2003). However, reallocation of road capacity measures requires investment in operation of urban traffic control (UTC) systems. If access control is needed in reducing road capacity such as the closure of streets, investment and operating cost for the enforcement of access control technology may be needed. Reconstruction cost for pedestrian areas is sometimes needed to be paid, too.

4.1.2 Implementation actors and processes

A typical allocation of tasks when implementing physical instruments (mainly zones or dedicated lanes, but can be applicable for other measures, too) can be the following – structure of involved internal and external bodies and actors (LEDA, 2003):

1. Planning:
   - internal: technical traffic department of the police, technical department of traffic works, the mobility department, department of urban development;
   - external: the local public transport company, the ministry of transport.

2. Implementation:
   - internal: the same partners + executor companies;
   - external: the same partners.

3. Enforcement:
   - internal: responsibility of the police, if necessary;
   - external: not responsible.

4. Monitoring:
   - internal: the police department, monitoring violations; the mobility department, monitoring the traffic flow;
   - external: the public transport company, assessing the circulation.

Improving communication between the parties affected can help to avoid potential barriers. On the other hand, a lack of dialogue amongst different departments can represent relevant barriers to implementation. To ensure the co-ordination and co-operation of different departments, several possibilities are given. In some case studies investigated in the TRANSPLUS project (TRANSPLUS, 2002), already existing departments such as the urban redevelopment department were responsible for the co-ordinated implementation of all measures while in other cases new organisations were found. Another solution is to establish interdisciplinary working groups within the administration consisting of representatives from various departments, such as for example the department of transport, planning or environment. The main aim of their establishment is to clarify objectives and to obtain mutual consent in preliminary stages of the realisation.

Physical restrictions such as dedicated lanes or zones can be controversial for a variety of reasons (CAPTURE, 1999):

- they may be seen as taking away space from other vehicles and lead to delays. The schemes may not get past city authorities if they are seen as likely to have an adverse impact on other traffic. In general this means that the design stage will require ensuring that this does not happen and providing evidence to other authorities that there will not be adverse impacts;
- more commonly, traders may object to the schemes if they have any effect on the parking of vehicles outside their premises.

Even though the extent of these physical measures is relatively small, there is often a rather large discussion regarding the restrictive (to drivers) nature of them. The aim of the improvements is to realise equal opportunities for cycling/walking, PT and motorised individual traffic. Nevertheless a lot of politicians and a great part of the population see the measures only as anti-car. In that the press generally stresses negative side aspects of a story, positive and objective articles in newspapers are rare (LEDA, 2003).

A large issue in terms of implementation ease is concerned with the degree of restriction that is imposed. A scheme which has wide ranging and radical effects is likely to be opposed more than one which does not. But if two stages are needed there may be more opposition to the second phase of a scheme. Planners need to consider the amount of restriction that will produce the aims they are interested in (CAPTURE, 1999).

Considering the former possible barriers, participatory approaches are valuable to provide opportunities for people to better understand the policies and projects, and participation of citizens may help to increase the acceptability. Generally, planners and decision makers are aware that acceptance of citizens and other parties affected is one precondition for the success of a project. Being involved in urban and transport planning processes, citizens are offered the chance to influence planning in the way to create structures which allow them, for instance, to reduce the distances for their everyday mobility, contributing also to identify possible alternatives to achieve the planned goals. On the other hand, citizens are encouraged to reconsider and change their mobility behaviour (TRANSPLUS, 2002).

The key would seem to take a step by step approach: every new initiative is likely to have its opponents, and a large scheme is likely to have more opponents than a small one. Thus, if some restricted areas can be introduced which provide real benefits to the people of a city, it will be likely that others will follow more easily than if it is all attempted at once (CAPTURE,1999).

There are also other facts supporting the principle of gradual implementation. Perhaps the most important is that *dedicated networks* can mostly only be realised in steps and therefore priorities must be established according to criteria such as for example the connection of tracks, rebuilding of streets in favour of preferred transport forms/users, avoiding dangerous situations etc (TRANSPLUS, 2002).

4.1.3 Likely impacts

The general effects of physical restrictions (like zones or dedicated lanes) can be synthesised as follows (KONSULT, 2003):

- demand impacts: a decrease in demand for car travel and conversely increase in public transport, walking and cycling is expected when road capacity for car use is reallocated. However, impacts vary according to the capacity of a network at the site where a physical restriction is implemented. The nature of the network and the existing level of congestion affect the ability of traffic to change route, vary journey time and make other responses. In some cases, when capacity is reduced on one road, but there is still available capacity on other routes or other times of the day, diverted trips such as re-routing and re-timing occur, and congestion spreads out over time and space. Dedicated bus lanes may have also important side effects as a drop in average speed of cars and trucks as fewer driving lanes are left for private transport. As a consequence, congestion costs for the users of these modes will increase;

- supply impacts: there are some decreases in the supply of road space for car use, where road closures or changes to pedestrian area are implemented to reduce road capacity, and bus priorities or cycle lanes are implemented reallocating road capacity. Conversely, other transport facilities increase in supply like bus lanes, pedestrian areas and so on. However, total transport spaces in some regions usually do not change;
- impact on key policy objectives: physical restrictions are implemented to reduce car use and to promote alternative transport. They encourage people to reduce their overall level of car traffic use in the city centre by switching from car to other modes. Also, they will contribute to a liveable, attractive and safe city centre. However, if capacity is reduced on a few roads or areas but there is still capacity available on other routes, drivers may divert onto an alternative route which still has available capacity. This will reduce traffic congestion on a specific road, but not lead to an overall reduction in the level of car traffic in an urban area;
- mitigation of adverse impacts: physical restrictions have the potential to contribute to the alleviation of a number of key problems. For example they can mitigate community severance, enhance the accessibility for those without a car and those with mobility impairments, and moderate the number, severity and risk of accidents;
- winners and losers: those who use priority transport modes (like PT, HOV, cycling and walking) should benefit from reduced congestion. If effective measures of parking control and/or public transport are not introduced there can be some losers through increased traffic congestion.

It is worth considering some additional, more specific impacts observed for implemented pilot projects (CAPTURE, 1999).

Bus lanes can decrease travel time, increase punctuality and reliability and reduces cost of operation. The segregation of traffic may also enhance safety. Combined with traffic management, adverse impacts on accessibility can be minimised. However there are also some drawbacks or *caveats* to be considered:

- bus lanes not always succeed in terms of their usually stated goal of speeding up public transport operation. Here mainly the overall growth in traffic or problems of enforcement can be cited as reasons;
- in most cases the lowering of delay time is not very large, and may be negative. The reason is that many of the delays associated with bus operations are not concerned with congestion delays, but with delays associated with boarding and alighting times;
- in general, private car speeds have not been slowed down by the measure (except some particular cases);
- the energy use impacts of bus lanes are generally favourable for buses – if there is less acceleration and braking due to smoother flow –, but the effects may be positive or negative for other traffic depending on details of design;
- the modal shift effects of the introduction of bus lanes are – in the short term – not as high as might be anticipated relative to the visibility that they appear to have within a city, and on a corridor. It would seem that for a bus lane to be successful requires that an overall corridor approach is taken and that the number of buses needs to be quite high to give a message to the public that the lane will lead to shorter journey times. In the longer term picture may be better: changes in behaviour take time.

HOV lanes have a similar effect as bus lanes in terms of increasing transportation efficiency and in terms of the use of road space. They are expected to encourage ridesharing and thereby reduce congestion, travel delays and air pollution. If they work efficiently they can further increase the capacity of the lane for carrying people, by using the spaces which buses do not use. In addition, again if they are operated efficiently, the use of the HOV lane for high occupancy vehicles may increase the flow of other traffic on the other lanes. While a bus lane built into an existing roadway may reduce capacity for other vehicles, that impact will be less with an HOV lane, instead of a bus lane[17].

Some evidence of past experience is worth of mention:

- Trials in an arterial corridor in Leeds since 1998 suggest traffic flows had fallen by around 14% after the implementation of HOV lanes. Average car occupancy in the morning peak has risen from 1.35 to 1.41 for the road as a whole, and 2.19 for the HOV lane (Leeds City Council, 1999). Experience elsewhere has suggested that HOV lanes can provide greater benefits than conventional bus lanes, provided that the delays to buses are not great. The bus operators in the Leeds scheme, have reported time savings of 3-6 minutes along the 1.5 km HOV lane section.

- The Madrid HOV lane is a separate lane in the middle of an arterial road and is used in the direction of rush i.e. towards the city in the morning and the opposite direction in the evening. It leads directly to the bus station where it then is possible to change to the underground system at a new inter-modal terminal. The service frequency of individual commercial buses did not increased, but a number changed their itineraries. Now there are several companies offering services in the corridor, so that the overall service frequency increased. In addition there was an increase in speed and service regularity, a decrease of travel time, a decrease of space use (bus users), a decrease of congestion, a decrease of energy consumption, a decrease of pollution, and a decrease of crashes.

- Also in Budapest, dedicated bus lanes are located in the middle of the street of three main roads. The bus lanes run partly on tram tracks, and buses drive in the opposite direction of a one-way street. The measure was implemented in three locations where the problem of congestion was extremely bad. The objectives were to relieve these areas of congestion and strengthen public transport. In two locations the measure was particularly successful in that public transport became much faster than car traffic. On the other hand, congestion was only slightly reduced on the remaining lanes used by cars. The measure failed in the other location due to a lack of enforcement of parking regulations. Here congestion became worse because the bus lane is the only free lane whereas the car lanes are congested with parked and circulating cars.

- In Helsinki, one of the five radial traffic sectors is operated only by buses using a 24-hour bus lane as the others are served either by underground or local rail. There are no major differences in the service levels of the five sectors.

In general, as it regard the effectiveness of dedicated networks, there are two main lessons learned from existing case studies. Firstly if physical measures are carried out on a large enough scale they can have an important effect on operational efficiency which translates into modal shift. Secondly, measures planned need to provide guaranteed priority (using proper enforcement techniques) to reach their goals regarding influencing traffic flows.

[17] An interesting paper about the efficiency of HOV and HOT lanes was written by Safirova et al. (2003), Are HOT lanes a hot deal ?, Resources for the Future, Urban Complexities Issue Brief 03-03, www.rff.org

4.1.4 Interactions with other measures

The creation of bus lanes provides the potential for later modal change. If pricing or other measures are introduced and the public transport alternative is of poor quality it is likely that people will carry on using a car, but pay more for it. But if bus lanes and other priorities have been put in place many more will choose the bus option. Urban traffic control (UTC) systems help the efficient operation of road capacity reallocation measures such as bus priorities/lanes (CAPTURE, 1999).

The road space remaining for general traffic can be quite unable to carry current traffic flows when introducing physical restrictions. One serious consequence of this is that the costs and reliability of freight transport could get worse. Thus, it may be that a necessary component of such a scheme would be demand management - perhaps by a method such as road pricing - to restrain general traffic flows to a level which the general traffic network could carry, or allowing freight transport to benefit from bus/HOV priorities (CAPTURE, 1999).

Other accompanying measures, such as park and ride schemes may often increase overall transportation efficiency by discouraging private cars from entering the city at all, thus reducing traffic levels on radial routes. Schemes will very often involve the making of a simpler road network which will reduce the number of junctions and thus increase capacity (CAPTURE, 1999).

The KONSULT database suggests the use of following complementary measures to physical restrictions (KONSULT, 2003):

- instruments to overcome organisational and financial barriers: intelligent transport systems;
- planning and regulatory instruments to overcome political barriers increasing acceptability: development densities including an increase in density throughout road capacity reduction area to reduce the need to travel, development pattern designed to encourage use of public transport; flexible working hours, car clubs, ride sharing; all forms of public transport, public transport service levels, PT fleet management systems; bus priorities, cycle priorities; traffic calming measures, regulatory restrictions, parking controls;
- economic instruments: PT fares structures, concession fares of public transport; parking charges, urban road charging.

4.2 Restriction of car use by introduction or expansion of pedestrian areas, limited access zones, car-free neighbourhoods, traffic calming

Restrictions to car use are mainly exemplified by the implementation of various regulatory strategies to limit automobile travel at a particular time and place. These restrictions may include a range of measures, that concern walking strategies and individual car use measures.

While implementation of car-free zones may also embody physical measures of pedestrian network improvements/ expansion of pedestrian areas, actions aimed at creating restricted-access areas represent regulatory measures that impact on the traffic flow in and out a certain area at a certain designated time. On the other side, traffic calming facilities are a complementary physical instrument that hold a sway on the individual car use. The table below exemplifies the clustering of these measures (in bold type) according to the category (physical or regulatory) of instrument they belong to.

Table 3 : Urban instruments concerning restriction of car use

Supply of land, infrastructure and technologies	*Use of transport infrastructure and technologies*	*Physical instruments*	*Regulatory Instruments*
Infrastructure: **Transport Networks**	**Walking**	Pedestrian areas: • **Creation of pedestrian areas**	• **Car Free Zones**
	Individual Car Use	Roads: • Expansion of existing road network • Road maintenance and clearing priority • **Traffic calming facilities** • Access control devices	• **Restricted access at certain times** • **Restricted access to vehicles that do not meet certain standards** • Speed limits

The following sections will endeavour to accurately describe the typology, implementation processes and impacts, as well as interaction with other measures, of car-free zones, pedestrian networks improvements, car-restricted areas, and traffic calming measures.

4.2.1 General characteristics

Car-free planning is a transport demand management strategy aimed at designing special areas and times for minimal car use, by means of the operation of a car-free district/area, or the establishment of a pedestrian zone in a definite area of a neighbourhood/town/city. Car-free areas may be implemented in different contexts:

- high-density urban areas (spots featuring multi-story buildings with mixed land use, i.e. housing, shops and offices adjacent to each other, with a population density of more than 30 residents per acre of land);

- medium-density urban areas (areas with 2-3 story building, and shops within residential neighbourhoods, with a population density of 15-30 residents per acre of land);

- commercial centres (a cluster of commercial activity, including central business districts (CBDs), minor commercial districts, and malls.), which are typically multimodal, with automobile, truck, transit and pedestrian access.

Higher density areas rely more on walking, cycling and transit, and less on driving. In such conditions, clustering and the quality of pedestrian conditions are important prerequisites. Areas with low densities, single land uses, and more dispersed destinations are car-dependent, and not very accessible by other modes, thus not suitable for the implementation of car-free concepts.

A car-free area/neighbourhood can be created either through a road space re-allocation of the rights of use of the existing infrastructure from motorists to pedestrians (e.g. commercial pedestrian areas) or through the planning of new car-free developments (housing developments).

In the first case, an area of the city, in general a high-density commercial, residential or resort area (e.g. a city centre) is closed to motorised traffic: the access can be either prohibited or discouraged, and walking, cycling and sometimes motorcycle access is guaranteed. In the second case, new urban developments can be planned in such a way that the need for motorised mobility is reduced and the use of motorised traffic is not allowed or made difficult (e.g. no parking places are available except for a limited number for shared vehicles).

Once a pedestrian area is established, some minimal requirements must be assured in order to keep the area attractive and lively: for instance, the area should be equipped with a pleasant urban environment (greenery, rain covers, decorated pavements instead of asphalt, fountains, benches, etc.) and could host activities such as markets, concerts and others; various activities should be located in the area - shops, offices, houses, etc; accessibility must be guaranteed through adequate public transport services and the provision of parking spaces outside the car free area; in general, high security and maintenance standards are expected. In the case of pedestrian area residents' access must be regulated, as well as the entrance of freight vehicles serving commercial activities. The size of the effect on the overall urban system depends on which ancillary instruments are implemented (see later).

Limited access zones are those areas where particular vehicle restrictions apply as well as regulatory strategies to limit automobile travel at a particular time and place. Driving can be restricted based on vehicle license plate numbers. This is typically implemented as a temporary measure during air pollution emergencies, or to reduce traffic congestion during major events. A few vehicle restrictions usually include various exemptions. For example, certain types of vehicles may be allowed in car-free areas or be exempted from no-drive days. Such exemptions may be controversial because those who qualify sometimes abuse their privileges. For example, if vehicles used by people with disabilities are allowed to drive in car-free areas, people may exaggerate a minor disability, and those who have such vehicles may lend them to able-bodied friends. If medical professionals are exempt from car-free days, they may use them for leisure travel as well as critical professional trips. Motorists who do not qualify for exemptions may sometimes have a critical need to drive. One solution to this problem is to provide each resident with a limited number of exemptions (for example, giving each household five tickets each year that allow one vehicle trip that would otherwise be prohibited) or by allowing motorists to drive under otherwise restricted conditions if they pay a special toll. This gives motorists additional flexibility.

The most radical form of car space restriction includes *car free development*, aiming to create car-restricted neighbourhoods. Two main approaches can be distinguished:

- *Planning of new activities*, i.e. the creation of new sustainable urban structures. In this case, car-free concepts often are implemented as c*ar-restricted neighbourhood* and the d*evelopment of new industrial or commercial activities and restriction of parking space (ABC-like)*. The ABC location policy is designed to help reduce the growth of car travel, and aims to match the mobility needs of businesses and amenities with the accessibility of different locations[18].

- *Restriction of car use in the existing urban space*: this approach tries to modify existing structures and can also lead to an integrated policy of sustainable transport and land use. Car restriction in this area means mainly to reduce the space or the access for cars. The reallocation of existing urban space could involve the following strategies and policies:

    1. *Accessibility regulation*: these sets of measures allow only certain types of vehicles to enter a specific area, according to characteristics associated with individual vehicles and their usage, such as time of day/week, vehicle type, user type (resident, visitor, etc.), duration of stay, etc. Traffic management tools like an automatic vehicle identification technology facilitates the application of such measures over a sufficiently large area
    2. *Parking policy*: parking space limitation is a measure to reduce the possibility of parking a car in the city and in this way it pushes car riders to other means of transport. It can be implemented as global measure for the city centre or in a more selective way to different locations. Different approaches may be adopted, e.g. reducing the supply of spaces, restricting the duration of parking or the opening hours, regulating their use through permits or charging and/or promoting the pre-booking of parking.[19] Here we refer more strictly to the limitation of physical space for car parking, which is obviously a more permanent "hard" measure than other parking regulations.

As for *traffic calming*, this measure represents the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behaviour and improve conditions for non-motorised street users. Traffic calming focuses on improving neighbourhood safety, comfort and liveability, while maintaining necessary levels of traffic circulation and emergency access. It involves a broad array of traffic engineering, education, and enforcement techniques to slow and disperse or re-route traffic.

Traffic calming requires much detailed design, as the range of tools available are very wide ranging and have to be chosen depending on the local circumstances. There are several best practice guides, and manuals available, which provide ideas for the design of schemes. But there is still the requirement for a very detailed local knowledge to know which types of measures will be effective and acceptable in different circumstances (CAPTURE, 1999).

Traffic calming measures can be separated into two groups depending on what transport aspect they are intended to limit: volume or speed (KONSULT, 2003; Traffic calming homepage, 2003). Volume control measures include:

[18] see also Sect. 7.3.1 of this deliverable
[19] parking measures are discussed in chapter 8 of this deliverable

- full closures,
- half closures,
- diagonal diverters,
- median barriers,
- forced turn islands.

Speed control measures include:

- vertical deflection measures: speed humps, speed tables, raised crosswalks, raised intersections, textured pavements;
- horizontal deflection measures: traffic circles, roundabouts, chicanes, realigned intersections;
- horizontal narrowing measures: neck downs, centre island narrowing, chokers.

It is common in practice that the mentioned measures are combined with each other. A combination of measures can create a “labyrinth”, which makes through movement difficult. Their primary purpose is to discourage or eliminate through traffic and divert it to surrounding streets. But the extra traffic on surrounding streets can add to congestion and environmental intrusion there, and this trade-off needs to be carefully considered at the design stage. Traffic calming may also reduce accessibility for those living in the area, and this loss of accessibility has often led to the rejection of such measures by the residents whom they are designed to benefit.

The table below provides sample cost estimates for various traffic calming measures (KONSULT, 2003). These estimates cannot replace detailed cost estimates using quantities and local unit prices for work items associated with specific projects. The estimates in this table may be useful in conceptual planning, as they show order of magnitude differences among measures. Costs increase quickly when measures require landscaping, drainage improvements, or land acquisition. However, besides the programme and enforcement expenses, a full cost evaluation should include increased travel costs and reduced mobility for motorists, and possible spillover effects, such as increased driving at other times or in other areas (an ineffective car restriction programme that reduces access in urban areas may even increase sprawl by encouraging business and residents to choose suburban location, with adverse impacts on total journey distances).

Table 4: Cost estimates for various traffic calming measures

Types	*Measures*	*Cost estimates*		
		Portland	*Sarasota*	*Seattle*
Volume control	Full closures	-	-	120,000
	Half closures	40,000	-	35,000
	Diagonal diverters	-	-	85,000
	Median barriers	10,000 – 20,000	-	-
Speed control	Speed humps	2,000 – 2,500	2,000	2,000
	Speed tables	-	2,500	-
	Raised intersections	-	12,500	-
	Traffic circles	10,000 – 15,000	3,500	6,000
	Chicanes	-	-	14,000
	Centre islands narrowing	8,000 – 15,000	5,000	-
	Chokers	7,000 – 10,000	-	-

US$, 1999 prices
Source: ITE and FHWA

4.2.2 Implementation actors and processes

In order to implement car restriction measures more effectively, a comprehensive approach integrating land use planning and transport planning is required. Restriction can only work if alternatives are presented, like fluent accessibility for pedestrians and cyclists, but also for public transport. For instance, a car free neighbourhood without the implementation of alternative modes (public transport, car sharing, non-motorised modes, etc.) will be unsuccessful (TRANSPLUS, Deliverable 3.3).

Pedestrian areas can be realised through municipal planning or through development of a particular project (e.g. urban housing complex). Car free commercial centres are often part of a downtown revitalisation programme or community renewal efforts. Although the scope of a housing development scheme is creating a car-free area, where parking provisions are limited to shared vehicles and possibly to visitors' vehicles, various approaches are possible. Legislative interventions or regulation have been used from some cities in order to regulate the issues of parking provision and of households' car ownership. In particular, laws can be issued to delimitate the pedestrian area and/or to prohibit the provision of on-street or off-street parking spaces (e.g. the project GWL-terrein project implemented in Westerpark area in Amsterdam, the Nippes/EAW project in Cologne, etc.).

For what concerns households' car ownership, cities adopted a variety of solutions: the most of them opted for a guarantee not to own a car/not to apply for a parking space within the area and in the bordering area, included as a clause in the rental contract (e.g. Bremen: Grünenstraße, Hamburg: Saarlandstraße, Kassel: Messeplatz / Unterneustadt, Munich: Kolumbusplatz II, Vienna: Floridsdorf, etc.). It is possible that potential households oppose to signing no-car ownership agreements, since they feel it as a restriction of individual freedom. Moreover the actual feasibility and legality of such agreements has to be checked against national and local legislation and institutional asset. For these reasons, other cities preferred to ask for a more informal letter of intent (e.g. Amsterdam-Westerpark: GWL-terrein, etc.), or even not to impose any legal interdiction to owning a car (e.g. Berlin – An der Panke, Edinburgh: Slateford Green, etc.). In this case, the implementation of the car free neighbourhood should be guaranteed by the lack of parking places within the housing development area and the construction of adequate pedestrian and bicycle routes to access the area.

As illustrated in the table below, the planning and development of a car-free area in certain areas and by certain stakeholders and/ore public institutions fits better in high-density urban areas, or in the framework of commercial centres, which are often part of a downtown restoration plan or community renewal efforts. Car-free planning has more chances to succeed once public bodies involved in the definition and execution phases are municipal or local authorities, implementing the project in the framework of municipal planning or through development of a precise urban renewal project.

Table 5: Rating of the aptness of car-free planning according to geographic areas and involved stakeholders

Geographic	**Rating**	**Organization**	**Rating**
Large urban region	**2**	Federal government	***1***
High-density, urban	**3**	State/provincial government	***1***
Medium-density, urban/suburban	**2**	Regional government	***2***
Town	**2**	Municipal/local government	***3***
Low-density, rural	**1**	Business Associations/TMA	***2***
Commercial center	**3**	Individual business	***1***
Residential neighborhood	**2**	Developer	***1***
Resort/recreation area	**2**	Neighbourhood association	***2***
		Campus	***2***

Ratings range from 0 (not appropriate) to 3 (very appropriate).
Source: Online TDM Encyclopaedia.

In addition, one of the cornerstones of a car-free area is the availability in the town of a transport system that provides faster and cheaper movement of passengers than the urban automobile. Indeed, car-free planning tends to be most feasible and accepted in urban areas with good travel alternatives (public transport, cycling and walking) and suburban parking spots.

Also, strategies of increasing the efficiency of freight and commercial transport (e.g. goods shipment to businesses and from retail businesses to customers' home) are an important constituent of the car-free planning.

Besides car restriction, another strategy is to facilitate the introduction or expansion of pedestrian areas fostering *pedestrian-friendly site development*. The provision of a comprehensive infrastructure as well as the implementation of mixed use and increasing density are important conditions for walking and cycling but must be supplemented by measures improving the urban design. As the speed of pedestrians allows them to perceive their environment very well, an interesting, varied architecture and urban design is important for the promotion of walking. Furthermore, green corridors (for example trees between streets and cycle tracks / footpaths) help to improve both the visual and the climatic situation reducing negative impacts of motorised modes (TRANSPLUS, Deliverable 3.2). The shaping of the environment is a main element as pedestrians require a pleasant change, seating, spaces to stay etc. For example elements such as arcades are both aesthetic and functional as they protect from weather. Protection against weather is required especially at station where pedestrians have to wait. Tracks in an attractive environment may encourage people to walk or cycle on longer distances. Besides visual attraction, acoustic impact influence the choice of non-motorised modes, too. Therefore, planning for pedestrians requires high creative quality in a confined space and thus, conscious dealings with buildings, places between buildings, colours, vegetation etc. In the past principles of that kind were pursued in all settlements leading to spatial structures of high quality in historical cities and villages.

As a whole, policies that target on non-motorised modes promotion must take different aspects into consideration:

- integrating transport and land use policies: planning for pedestrians and cyclists must consider the need for short and direct connections without neglecting the elements of safety and convenience. Therefore, the development of both short distance structure and pedestrian and cycle friendly sites are important elements.

- multi-modal approaches: walking and cycling must be seen in the interrelation with other modes. Strategies such as improving cycle infrastructure must be completed by approaches discouraging car use as well as connecting walking / cycling with public transport. The promotion of non-motorised modes is often combined with car restrictions reducing negative impacts of motorised modes (e.g. TRANSPLUS case studies of Ghent, Belgium and Tübingen, Germany) as well as improvements of transport intermodality (e.g. Ålborg, Denmark and Ghent analysed in TRANSPLUS).
- walking and cycling must get the same status as public transport in planning and funding and the development of comprehensive programmes which include a range of different approaches from physical implementation to educational programmes is required. In addition, the creation of attractive conditions for walking and cycling must supported by "soft policies" to ensure / increase their acceptance

As concerns the *traffic calming measures*, their implementation varies greatly between cities, areas, countries, and at different times through history (CAPTURE, 1999). In countries where it has become common it is generally easy to implement. The design ideas are known, and the concept is generally very popular, although many can perceive negative aspects such as visual intrusion, displacement of traffic, increased noise and (sometimes) fumes; cyclists often perceive problems with techniques such as chicanes. But as long as bodies such as the emergency services, and public transport operators are consulted at the planning stage there is generally much positive support for these schemes by local stakeholders and residents.

A traffic calming scheme implementation process is composed of four major phases:

- planning: scheme conceptualisation, planning and design, promotion, approvals and legal arrangements;
- funding: scheme funding for start-up and for continued operation;
- commissioning: construction, purchase and installation of equipment, planning of operations, public information and initiation of operations;
- operation: day-to-day provision of services, maintenance and enforcement, as well as continuing evaluation and improvement of the system.

The main barriers to implementation can be summarised as follows (KONSULT, 2003):

- finance: traffic calming measures can be implemented with low costs basically, but for area wide treatment their cost might be significant;
- political: decrease of accessibility can be controversial for the residents within the treated area, and diversion of traffic for those outside;
- feasibility: acceptance by the local community and co-operation of relevant institutions is the key feasibility issue. Aesthetics have often an important influence on acceptance.

While the interaction and conflicts of interests between institutions is a frequently recorded obstacle to implementation, there is no evidence that a large number of actors in a complex decision process is needed to bring this about. Two, or at the most three, such groups will generally suffice. The general findings have been that the effects of physical measures on the public's perception of transport in a city have been beneficial. The benefits have been generally perceived by bus users and there have generally been few complaints by car users. There have, however, been complaints by businesses in some cases. These have generally related to measures which reduce on-street parking, which seems to be a major concern of many businesses.

Another important conclusion of CAPTURE is that measures which reduce traffic in areas of cities tend to be very visible, involve several bodies, and are almost certain to contain elements which will be unpopular with sections of the community. But carrying through a plan to its conclusion will usually result in a scheme which benefits the city. Real benefits can come in the form of less traffic and a more congenial environment within the area affected. However, basically financial resources and local conditions will largely determine what can be done in the field of traffic calming.

It is worth considering some general recommendations (derived from the experiences of related pilot projects) which can help to overcome the mentioned barriers:

- public consultation is one of the keys to successful implementation of traffic calming schemes. There will be strong views from sub groups of the population affected. In the process of dialogue new solutions may be found which all parties will support;
- while physical measures which reduce traffic in an area will almost certainly have some opponents, they will also (if well planned) have strong support from other people. It is much easier to implement speed limits and access controls to reduce traffic in an area than implementing road pricing (this fact has been highlighted in project MC-ICAM as well);
- there is often fear in cities that measures which restrict car traffic will result in chaos. Once they have been implemented support grows rapidly. It is recommended that cities start with experimental or small scale schemes which will have obvious positive benefits, before attempting a radical scheme in a city with no history of change.

4.2.3 Likely impacts

Impacts stemming from the implementation of car restriction measures often concerns travel patterns, and depend on how restrictions are applied and the quality of transport alternative. By reducing vehicle traffic such restrictions should facilitate more clustering or compact development, and the formation of more accessible, less car-dependent communities.

Geographic restrictions on automobile travel, such as prohibitions on driving in a downtown area, may simply shift car trips to other parts of the urban region unless it is implemented with other disincentives to driving and improvements to walking, cycling and public transit.

Similarly, restrictions based on license numbers have a number of problems (Goddard, 1997 and on-line TDM Encyclopedia):

- Many trips are simply deferred, not eliminated. If a motorist planned to go shopping by car, they will simply put it off until the next day, resulting in no actual reduction in mileage or emissions.

- Many wealthier households purchase a second car with another license number, so they have one available every day. These tend to be cheap, older, high polluting vehicles. Mexico City recorded a jump in the number of vehicles owned due to this policy.

- A large portion of vehicles must be exempted, including any vehicle used for business (taxis, delivery vehicles, vehicles used for construction work, etc.), and many professionals (doctors, salespeople, consultants, etc.) demand exceptions based on their professional needs.

For these reasons, a program that prohibits each vehicle from driving 20% of days does not necessarily result in a 20% reduction in total vehicle travel. Actual travel reductions are likely to be half that amount or less.

Table 6: Travel Impact Summary stemming from limited-access zones implementation

Travel Impact	*Rating*	*Comments*
Reduces total traffic.	**1**	Depends on measures implemented.
Reduces peak period traffic.	**2**	For time-based restrictions.
Shifts peak to off-peak periods.	**2**	For time-based restrictions.
Shifts automobile travel to alternative modes.	**2**	
Improves access, reduces the need for travel.	**1**	Reduced traffic can improve cycling and walking conditions.
Increased ridesharing.	**1**	
Increased public transit.	**3**	
Increased cycling.	**3**	
Increased walking.	**3**	
Increased Telework.	**1**	
Reduced freight traffic.	**0**	Freight vehicles are usually exempt from such restrictions.

Rating from 3 (very beneficial) to –3 (very harmful). A 0 indicates no impact or mixed impacts.
Source: online TDM Encyclopaedia.

When they are effective, vehicle restrictions can reduce traffic congestion, road and parking facility costs, crash risk, pollution emissions and local environmental impacts. They can improve community livability. Restricting urban vehicle traffic can have substantial safety benefits as well. Because such programs tend to be implemented in areas and at times when vehicle impacts are greatest, these benefits can be significant. The actual magnitude of benefits depends on circumstances.

An interesting evidence is provided at this regard by a study on the influence of driving behaviour on the emissions of NO_X, HC, PM, CO, SO_2 and CO_2, commissioned to the VUB and TNO by the regional government of Flanders, in the context of the environmental policy plan (see VUB 2002). Although this report does not provide any information on the costs associated with policy measures, it does provide crucial information on emissions avoided by influencing driving behaviour and by infrastructure options. Two types of measures were analysed to determine their influence on fuel consumption and vehicle emissions: traffic calming measures influencing driving behaviour on a local scale (plateau humps, 30 km/h zone, green wave, roundabouts…), driving behaviour itself and on-board systems. Two methodologies were used to obtain emission reduction results. A first methodology uses measurements in actual driving conditions, which lead to driving cycles that are performed on a number of vehicles in laboratories to deliver final results. A second methodology uses the Vehicle Simulation Program (VSP) developed by VUB. Final conclusions are made on the basis of the results of both methodologies.

The influence of *traffic calming measures* was determined on the basis of actual driving conditions, and repeated in reference driving cycles in laboratory conditions. The results of the measurements on 12 vehicles (7 petrol cars and 5 diesel cars) are summarised in the table below. Statistically non-significant results are indicated *n.c.* (not consistent, e.g. when there was no common trend among all vehicles tested).

Table 7: Overview on traffic calming measures and vehicle emission

		CO_2 [g/km]	CO [g/km]	HC [g/km]	NO_X [g/km]	PM [g/km]
Plateau humps	**Petrol**	+45%	n.c.	+25%	+55%	-
	Diesel	+55%	n.c.		+75%	+75%
30 km/h zone	**Petrol**	-10%	n.c.	-65%	-50%	-
	Diesel	-10%	n.c.	n.c.	n.c.	-35%
Green wave	**Petrol**	-20%	-80%	-75%	-40%	
	Diesel	-20%	n.c.	n.c.	-40%	-35%
Roundabouts	**Petrol**	+10%	-60%	n.c.	n.c.	-
	Diesel	n.c.	n.c.	n.c.	n.c.	n.c.

Source: VUB, 2002

As expected, some traffic calming measures influence local emissions considerably. However, plateau humps that reduce traffic speed have severely increased emissions for all vehicles and hence do not contribute to emission reductions. “Green wave” speed harmonization on the other hand has high emission abatement potential for urban areas. Roundabouts are reported to have emission potential for CO, but increased emission for CO_2.

Traffic calming measures have been also the subject of studies focused on noise and safety impacts. Studies on noise effects of traffic calming commissioned by the UK department (DETR) have shown that after the installation of road humps and speed cushions the maximum noise levels from cars are reduced. The overall traffic noise level is also reduced if the traffic stream is mostly cars. Typically the reductions achieved in an urban setting are in the range 4 – 7 dB(A). However, road humps and speed cushions have a more complex effect on noise from commercial vehicles. The net effect on overall traffic noise depends on the proportion of large commercial vehicles in the traffic stream and on the type of road hump installed[20].

As it concerns the impacts on safety, we can mention the results of the SWOV study which has performed a cost-effectiveness analysis of the roads safety measures in the Dutch national transport plan (NVVP). The NVVP aims to about 300 fewer deaths in 2010 and a decrease in the number of in-patients by 4.600. The study (SWOV Reports D-2000-09-I and D-2000-09-II) has examined the costs and cost-effectiveness of each measure. The calculated cost-effectiveness gives for very measure insight in the costs needed to reduce the number of victims by 1. The aim was to rank the measures by efficiency, and by that to help the government choosing the right road safety policies. It is notable that:

- the redesign of 48.000 km of urban road into zone 30 and similar profiles was accredited to reduce in total over 30 years the deads and in-patients of 671 units, with an investment cost per year of 58 million € and a very good cost-effectiveness ratio;
- almost the same result is achieved for another planned measure, the redesign of 8.500 km of urban roads into local arterials, including bicycle roads and roundabouts.

[20] See Phillips and Abbott (2001) for this.

As concerns specific travel impacts of *pedestrian areas*, these may cause substitution of longer car trip with relatively short-non motorised trips. Walking improvements also support public transport options and ridesharing (carpooling and vanpooling). It ha been observed that communities that improve non-motorized travel conditions often experience significant increases in non-motorized travel and related reductions in vehicle travel (PBQD, 2000). One study found that residents in a pedestrian friendly community walked, bicycled, or rode transit for 49% of work trips and 15% of their non-work trips, 18- and 11-percentage points more than residents of a comparable automobile oriented community (Cervero and Radisch, 1995). Another study found that walking is three times more common in a community with pedestrian friendly streets than in otherwise comparable communities that are less conducive to foot travel (Moudon, *et al*, 1996).

International studies find significant differences in non-motorized travel patterns. For instance, high levels of non-motorized travel in such geographically diverse communities, and lower levels in otherwise similar areas, indicate that transport policies and community attitudes are more important than geography or climate in determining non-motorized travel. Potential travel impacts are much greater if pedestrian improvements are part of Smart Growth development practices that increase accessibility, for example, by locating schools and shops within residential neighborhoods. Pedestrian areas improvements around worksites can increase transit and rideshare use, because without these employees may feel the need to have a car to run errands during breaks.

Travel surveys and traffic counts usually under-record non-motorized trips, because they ignore or undercount short trips, non-work travel, travel by children, recreational travel, and non-motorized links (BTS, 2000). One study found that the actual number of non-motorized trips is six times greater than what conventional surveys indicate (Rietveld, 2000). In 2000, the Southern California Metropolitan Transportation Authority increased the portion of non-motorized travel in their models from about 2% of regional trips (based on conventional travel surveys) up to about 10% (based on more comprehensive travel data from the 1995 National Personal Transportation Survey).

As a whole, non-motorized transportation provides a number of benefits and costs, among which one can include:

- *mobility benefits*: improved non-motorized transport conditions increase travel choice and mobility, which particularly benefits for non-drivers.

- *transport and land use benefits:* shifts from driving to walking can reduce congestion, road and parking facility costs, consumer costs, and pollution emissions (Litman, 1999). It can be particularly effective at reducing many costs because it most often substitutes for short automobile trips in higher density urban areas where the per-mile costs of driving tend to be highest. Non-motorized transportation supports other alternative modes (public transit and ridesharing), and Smart Growth land use objectives, including higher density, mixed-use development to increase access, and reduce per capita pavement.

- *safety and health benefits*: although non-motorized modes have relatively high per mile casualty rate, this is offset by reduced risk to other road users, and by the fact that pedestrians and cyclists tend to travel less overall than motorists. International research suggests that shifts to non-motorized transport result in overall increases in road safety. For example, the Netherlands has a high level of non-motorized transport. Pedestrian fatalities per billion km walked are less than a tenth as high as in the United States (Pucher and Dijkstra, 2000). Walking provides significant aerobic fitness Health and Fitness benefits. According to one major study, “Regular walking and cycling are the only realistic way that the population as a whole can get the daily half hour of moderate exercise which is the minimum level needed to keep reasonably fit.” (Physical Activity Task Force, 1995).

- *livability:* streets that are attractive, safe and suitable for walking are a key factor in community livability. Pedestrian-friendly streets create opportunities for people to meet and interact, helping to create community networks.

- *recreation benefits:* walking is one of the most common forms of physical recreation. Some people argue that transportation funding should not be spent on recreational walking facilities, yet a significant portion of motor vehicle travel is for recreation.

- *economic development*: in several case studies, improving walking conditions in a community significantly increased retail sales and property values (LGC, 2001).

On the side of equity impacts (online TDM Encyclopaedia), pedestrian areas and facilities improvements can benefit nearly everybody, although some people benefit more than others from a particular policy or project. These improvements in general, and improvements designs that accommodate the widest range of potential users, including people with mobility and visual impairments (disabilities) and other special needs in particular, are particularly important for providing basic accessibility and assure opportunity to who are transportation disadvantaged. Pedestrian safety improvements are particularly beneficial to economically and socially disadvantaged communities.

Improving walking conditions often requires public resources (money and land devoted to sidewalks and paths), but these costs are usually less than the public costs of an automobile trip. Litman (1998) describes how people who drive less than average overpay their share of local transportation expenditures, since their local taxes fund roadway expenses that are primarily needed for the sake of automobile traffic, so increased funding for non-motorized transportation is often justified for the sake of horizontal equity. Lower-income and transportation disadvantaged people often rely heavily on non-motorized transportation, and so benefit significantly by non-motorized improvements. Pedestrian transportation is often critical for providing basic accessibility.

As for the main impacts stemming in particular from traffic calming, they can be summarised as follows (KONSULT, 2003):

- demand impacts: traffic calming measures reduce vehicle traffic speeds and volumes, so that the main impacts of these measures can be to improve the environment and to reduce accidents. The purpose of segregation measures is to discourage or eliminate through traffic, but to induce diversion to other roads. The additional distance travelled is likely to add only marginally to the cost of the journey, however, and hence to have little impact on the number of journeys by car. Only where the network is close to capacity is demand likely to be reduced. It is unlikely that there will be significant change in demand response of traffic calming over time;

- supply impacts: the main impact on supply of traffic calming is to reduce the capacity of the road network. The scale of this will be greatest where traffic calming measures are applied to main roads. Reductions in capacity are also likely to be sizeable where segregation measures, using e.g. traffic cells, are implemented. In these cases, the connectivity of the minor road network is reduced, and through traffic and some local traffic is forced to use the main roads. The impact will depend on the extent of the measures, but it is possible to envisage reductions in capacity of as much as 10%;
- impact on key policy objectives: the immediate purpose of traffic calming is to reduce the speed and volume of traffic. Reductions in traffic speed and volume are means to other policy goals such as traffic safety and active street life, liveability and the local environment, but can also induce re-routing;
- mitigation of adverse impacts: traffic calming measures may contribute to the alleviation of a number of key problems (in particular community severance and number, severity and risk of accidents) through reduction of the speed and volume of traffic, but the scale of contribution is dependent on the individual measures. However, it has to be taken into consideration that there can be an increase of noise, local air pollution, etc. elsewhere from diverted traffic, furthermore traffic calmed areas can be less attractive due to reduced accessibility;
- winners and losers: people living in the target area can make advantages of traffic calming where reducing speed and volume of traffic inside the area can improve safety and environments, but the outside will suffer from diverted traffic. Large scale freight and commercial traffic may be among the potential losers, when reduction of speed results in increased delay on routes used by freight vehicles, and in reducing utilisation of freight vehicles making high value journeys.

Project CAPTURE has found that traffic calming can have major effects on modal split at the very local level, while the city wide modal shift effects of traffic calming measures are thought of as being negligible (CAPTURE, 1999). The effects are generally to remove some traffic from the traffic calmed area, and onto surrounding roads. At the same time the introduction of traffic calming can increase the attractiveness of walking in a local area and encouraging activities to be carried out in local areas, thus reducing the need for motorised transport to reach other areas.

The effect of successful traffic calming is generally to create a more pleasant environment for living and working, and it is therefore to be expected that the local economy will benefit in this way. However, it is likely that local businesses may perceive that fewer customers in cars will visit the area.

Hundreds of before-and-after studies were collected and then used to analyse impacts of traffic calming on speeds, volumes, and collisions. The following tables summarise some of the effects that have been detected after the installation of traffic calming measures.

Table 8: Speed (mph) impacts of traffic calming measures (standard deviations in parentheses)

Instrument	*Sample size*	*Average change*
12” humps	179	-22% (9%)
14” humps	15	-23% (6%)
22” tables	58	-18% (8%)
Longer tables	10	-9% (7%)
Raised intersections	3	-1% (10%)
Circles	45	-11% (10%)
Narrowing	7	-4% (22%)
One-lane slow points	5	-14% (4%)
Half closures	16	-19% (11%)
Diagonal diverters	7	-0% (17%)

Table 9: Volume (vehicle per day) impacts of traffic calming measures (standard deviations in parentheses)

Instrument	*Sample size*	*Average change*
One-lane slow points	5	-20% (19%)
Full closures	19	-44% (36%)
Half closures	53	-42% (41%)
Diagonal diverters	27	-35% (46%)
Other volume controls	10	-31% (36%)

Table 10: Safety (number of collisions) impacts of traffic calming measures

Instrument	*Number of observations*	*Change in collisions*
12” humps	49	-11%
14” humps	5	-41%
22” tables	8	-45%
Circles (1)	17	-29%
Circles (2)	130	-73%

Source for all tables: *Traffic Calming* organization, 2003

Environmental impacts of traffic calming (and similar) measures have been analysed in the framework of project CANTIQUE (CANTIQUE, 2000). For example introducing access control & speed limitation measures may result in changing pollutant emissions: CO +11%, CO_2 -3%, HC -17% to +0.4%, NO_x -4% to -10%. Traffic conditions have also been affected: vehicle km -1.3% to -4.6%, traffic volume -33% to -78%, travel time -18% to +10.9%, PT use +50%. Another example – the effects of traffic calming combined with a new tunnel: CO -5%, CO_2 -4.7%, HC -5%, NO_x -45%, average speed +3.7%, fuel consumption -1.6%, travel time -3%. A complex traffic calming often consists of several complementary instruments. For example the effects of traffic calming combined with pedestrianisation, new tunnel, metro, PT bus lanes and parking management were the followings: CO -5.1%, CO_2 -4.8%, HC -5%, NO_x –4.6%, average speed +3.9%, fuel consumption -1.8%, travel time -3.1%.

4.2.4 Interactions with other measures

Car-free planning, including car-free neighbourhoods and car-restricted areas, along with improvements of pedestrian facilities/non-motorised planning & management are reciprocally supportive measures that are often implemented together, also with the support of other transport-demand management strategies, land use management policies and the like, as reported in chapter 4.2.2. The table below show this interaction of “mutual support” among these measures that are part of the broad transport-demand management strategies.

Table 11: Interaction among car-restriction measures

	SUPPORTS	IS SUPPORTED BY
CAR-FREE PLANNING	- Traffic Calming - Public Transport Improvements - Non-motorized Transport Improvements - Car-sharing - Smart Growth * - Parking Management Universal Design - Location Efficient Housing	
LIMITED-ACCESS ZONES	- Car-Free Planning - Traffic Calming - Smart Growth - Commute Trip Reduction programs	- Public Transport Improvements
PEDESTRIAN AREAS & FACILITIES IMPROVEMENT (NON-MOTORIZED TRANSPORT IMPROVEMENTS)	- Universal Design/Accessibility - Integrated Planning - Institutional Reforms	- Public Transport Development - Commute Trip Reduction programs - Parking Management - Transportation Access Guides ** - Traffic Calming - New Urbanism *** - Security Concerns

* *policies that integrate transportation and land use decisions, for example by encouraging more development within existing urban areas where additional growth is desirable, and discouraging low-density, automobile dependent development at the urban fringe*
** *a document or set of documents that provide concise, customized information on how to access a particular destination by various travel modes, with special consideration of efficient modes such as walking, cycling and public transport*
*** *also called New Community Design, Neo-traditional Design, Traditional Neighborhood Development, Location Efficient Development and Transit Oriented Development, is a set of development practices to create more attractive and efficient communities*

Source: elaboration from on-line TDM encyclopedia

Simply closing off a street or neighborhood to automobile traffic may be unsuccessful if other factors are not supportive. Moreover, car-free planning requires that residents, businesses and public officials support the concept and its implementation. Some specific recommendations from the online TDM encyclopedia are that car-free planning should:

- include as complementary measures improvements in transport service, pedestrian and cycling conditions, urban environmental conditions, and implementation of other transport-demand management strategies; moreover, it should include parking measures and land use management; also, freight transport management is necessarily to be taken into account as an important component of car-free planning, including provisions for bulk deliveries to businesses, and from retail businesses to customers’ home.

- consider the mobility needs of people and businesses that currently depend on driving.

- involve stakeholders, including residents and businesses.

- provide accurate and timely information to users concerning where and when vehicle traffic is restricted, and the transportation options that are available.

- finally, implement car-free planning features on a part-time or temporary basis, and expand the program gradually.

Generally, as the promotion of sustainable modes usually requires a change in behaviour, hard policies should be supported by soft policies (information, participation). This means, that cycling and walking should be fostered both by the provision of infrastructure and the creation of awareness. Early participation of stakeholders can help to take account of different aspects as well as to identify potential barriers. Furthermore, comprehensive information on mobility may help to increase citizens' point of view and, thus, influence their choice of mode. These potentials should be used more purposefully by promoting the offer of corresponding services (e.g. demand management) to citizens.

As for traffic calming measures, the KONSULT database (KONSULT, 2003) recommends using additional instruments, like cycle lanes and priorities to overcome political barriers when implementing these measures. Conventional traffic management can contribute to compensate losers of traffic calming by e.g. mitigating the undesired effects of re-routing. It is also important to consider instruments being able to reinforce benefits of traffic calming. KONSULT suggests applying proper development densities, development pattern and development mix during planning processes. Ensuring alternative modes of transport, like park and ride, cycle routes, pedestrian routes and pedestrian areas can increase the acceptability of the rather restrictive measures. Using conventional traffic management tools, furthermore additional physical restrictions (e.g. dedicated lanes and priorities) and conventional direction signing and static direction signs are other complementing tools to make better advantages of applying traffic calming.

Finally, according to LEDA web-database (LEDA, 2003) a traffic calming measure generally consists of implementing several traffic calming devices on the area streets, based on the reshaping of mobility functions: creation of bus dedicated lanes, enlarged sidewalks, protected crosswalks, reorganised parking lots system, etc. It cannot be said that there is a direct relationship to further measures, but traffic calming has to involve also the improvement of the area's accessibility, e.g. by introducing new public transport lines. The increase of collective modes of transport should be added in order to make the measure more complete.

5. Urban freight distribution

5.1 City logistic terminals

City logistics encompasses measures affecting collection and delivery activities of logistic service providers in urban areas, aiming at the reduction or prevention of commercial traffic and its negative external effects (BESTUFS, 2003). One of these measures is the establishment of *city logistic terminals* (called also as *urban distribution centres*).

5.1.1 General characteristics

Urban activities require the supply of goods and the disposal of waste for consumption and production, so there is little scope for reducing goods flows to and from cities. Previous research has shown that the distribution of urban goods is not organised efficiently and that there is considerable scope for reducing urban goods traffic through co-ordination and consolidation of transports. The concept of city logistic terminals was developed in order to reduce urban freight traffic and to help the shift of long distance freight traffic from road to rail.

The urban freight best practice handbook (BESTUFS, 2003) defines the city logistic terminal as a place of transhipment from long distance traffic to short distance (urban) traffic where the consignments can be sorted and bundled. Its main purpose is to achieve a high degree of collection of goods flows in order to supply efficient transport from the terminal to the city centre and vice versa. They can be stand alone platforms of a single forwarder or an element in the logistic chain of huge companies. More common however is the integration into logistic urban networks.

The following are the latest trends leading to an increasing diffusion of city logistic terminals:

- the need for urban distribution and freight centres has been growing due to decreasing consignment sizes, higher delivery frequencies and smaller stocks;
- shippers tend to increasingly outsource their logistics activities;
- freight providers will increasingly find themselves barred from cities or city centres;
- urban distribution and freight centres can help in assuring the goods supply of a city and in handling the collection and delivery traffic efficiently;
- they offer potential for a broader use of city logistics solutions.

For city logistic terminals the location of the platform is one of the key implementation factors of success (Budapest city-logistics project, 2002). An excellent connection of the terminals to a (possibly multi-modal) transport network is obviously required.

The location also has a substantial influence on the traffic generated by the platform, and thus on its environmental performance. Land prices and concentrated local emissions through traffic attracted by the platform make it often difficult to find a suitable location. In order to reduce the roadside distribution transport mileage the platform would preferably be located close to the city and its commercial centres. On the other hand a central location usually involves high land prices and conflicts with the neighbouring residential areas that are sensitive to the attracted traffic. Due to the high land costs establishing a freight platform in the city centre will generally only be possible when public areas are provided or subsidies are obtained. Because of the traffic involved a location in the outskirts is often preferred. In any case areas suitable for a future freight platform should be identified early enough and secured by land use planning measures.

Although the idea of distribution and freight centres sounds very promising, particularly the target of increasing the efficiency of urban delivery by consolidating multi-company delivery has proved difficult to meet in the past. Various barriers in the real world have been identified (BESTUFS, 2003; Urban mobility project, 2002):

- lack of economic convenience (interruption of the transport chain at the distribution centre causes additional costs);
- lack of willingness to co-operate because of tight competition (fear of disclosing competitive information about order quantities, products, customers, know-how, etc., fear of loosing customers);
- reluctance to loose control over merchandise and transport chain, particularly the responsibility for the goods transported;
- loss of direct contact between the receiver and the delivering company (the act of delivering offers an opportunity for the transport company to establish a well functioning customer relationship);
- many companies give much higher priority to customer service and competitive advantage than to reduced transport costs;
- reduced need for multi-company consolidation because of the general concentration process in the transport-logistics business (for large retail companies with their own distribution network the benefit of goods flows consolidation is rather small).

5.1.2 Implementation actors and processes

Some interesting evidence on implementation issues can be drawn from the experiences of several pilot projects carried out and evaluated in the framework of BESTUFS thematic network (BESTUFS, 2003):

- the implementation of an urban distribution centre can be an integral part of the city logistics approach (like in Kassel, Germany) initiated by forwarding associations and the chamber for industry and commerce;
- the responsible unit of Ministry of Transport (e.g. the office of regional transport as in the case of Tenjin, Japan) can support the joint distribution systems in institutional ways. The regional transport office provides a platform for discussing related things and co-ordinating many stakeholders including shippers, freight carriers, residents and administrations who are involved in the systems;
- in Leiden (The Netherlands) the municipality decided that there should be a city distribution centre and that further measures should be taken to reduce the traffic volume in the city centre. The project was carried out as a public private partnership involving the municipality and private logistic service providers. The municipality provided loans to facilitate the actual start and the operation;
- in Graz (Austria) the city terminal project was realised as a Private Public Partnership (PPP), involving private carrier and forwarding agencies, the three largest banks of the region and the regional energy supplier. The region and the federal government were not directly in the partnership, but helped to finance the project. The operating company is owned by private carrier and forwarding agencies (more than 50%), the energy service

provider and the banks. Investment costs (about 130 Mill EUR) were covered by federal financing (about 60%) and by private investors (about 40%);
- the city terminal development in Hochrhein (Switzerland) is a private initiative of a group of local entrepreneurs. The terminal which is open to every paying customer will be operated by a consortium of several private and semi-private companies. The transhipment terminal is strongly supported by the government whose stated policy is to support modal shift from road to rail. Around 70% of the investment costs for the container terminal will be paid by the Swiss government. This direct and indirect subsidisation is linked to the amount of lorry equivalents transferred from road to rail by the operation of the container terminal.

A clear point made by many projects is the involvement of all parties, public and private ones. The degree of public intervention varies from one city to another. Projects range from an entirely private initiative, based on optional participation and the assumption that operators will be rational enough to co-operate, to a local authority initiative quite restrictive and often based on distribution licences. Particularly the latter case might imply the risk of monopoly (one carrier being given exclusivity for inner city distribution) or the risk of over-regulation.

A city logistic terminal can only be established if profitable for private transport companies. This can result from a variety of impacts: suitable spaces with efficient transport infrastructure, efficiently used combined transport, additional services provided directly on site, reduced distances to customers, etc.

Public support for city logistic terminals is justified by economical and ecological benefits: they increase the region’s competitiveness and may help to attract industry; moreover, intermodal freight platforms promote modal shift reducing long distance road transport. Public support can take various forms, such as providing land at low costs, securing of appropriate areas, direct subsidies, etc.

Local authorities have a significant role in implementing city-logistic measures. Their main tasks may include (Budapest city-logistics project, 2002):

- monitoring demand and supply on logistic services and harmonising them;
- giving active support to promoting the co-operation between market actors that is essential in establishing city logistic solutions and providing multi-modal hubs for freight transfer. City authorities can act as a facilitator or catalyst for sustainable solutions. A shift from individually optimal solutions to socially optimal solutions requires the involvement of all actors concerned;
- identifying suitable sites at an early stage and secure them by appropriate land use planning measures;
- shaping the framework conditions of the transport market by appropriate regulations that internalise external effects and ideally make the individual decisions of the competing actors converge in a socially optimal solution;
- providing the necessary transport infrastructure in order to guarantee the efficient access to the multimodal transport network;
- providing direct financial support for the establishment of transhipment terminals.

However, it has to be taken into consideration also the legal framework, which usually assign competences to municipalities in the field of urban and housing planning, urban transport, and parking. There are also the ruling of municipal traffic and the municipal detailed plans for specific areas. These instruments should include specific provisions concerning urban freight distribution and the operation of city terminals.

5.1.3 Likely impacts

The aims of city logistic terminals can differ according to category, local circumstances, spatial orientation (BESTUFS, 2003). There are two main reasons behind the development of such distribution centres:

1. the consolidation of goods flows (collection and distribution centre);
2. the facilitation of logistic activities (e.g. storage or transhipment).

The consolidation of goods flows aims at increasing the efficiency of the collection or distribution process, thereby reducing the environmental impact of urban delivery activities. By bundling various trips of one or several carriers to single trips with better capacity usage or smaller and cleaner vehicles, congestion and noise in the city can be reduced, time gained and delivery made more reliable.

The facilitation of logistic activities aims at realising synergies by concentrating business activities of one single company or between several companies. Such synergies can include synergies in planning and organising logistic processes, in infrastructure use, provision of internal services such as customs, security services, disposal services, information services, training and consulting or external supply of logistic activities of shippers, e.g. substitution of expensive inner city storage facilities.

When identifying the effects of developing city logistic terminals, it is reasonable to distinguish between public and private benefits (BESTUFS, 2003; Urban mobility project, 2002). The pilot projects implemented so far have shown mainly the following public benefits:

- less emissions through more efficient urban deliveries, i.e. a reduction in the number of trips;
- shift of long distance transport from road to rail;
- further traffic reduction in the urban region as trips to service stations can be avoided when these services are provided directly on site;
- stimulation of economic growth in the region (creation of jobs, establishment of new enterprises, improved supply to the industry) by improving the logistic infrastructure.

Private benefits (applicable to logistic operators and transport companies) are mainly focused on increasing efficiency by bundling consignments, using intermodal transport, participating in co-operations and attracting new customers. However the costs have to be taken into account, too. They may be caused mainly by:

- additional loading and storing procedures in terminals;
- longer transport routes to and from terminals;
- more complicated organisational tasks.

There is no clear answer to the question whether the mentioned benefits outweigh the costs. To complicate things, those who benefit are not necessarily those who bear the costs. Any answer would probably be context dependent. But if the city terminal creates substantial benefits for the public, it should also be actively supported by the public sector. This can be either by providing permanent subsidies, by active participation (co-ordination, promotion, initial financing), by establishing supportive legal framework conditions such as a lorry ban in the city centre or by supportive operational measures such as an extension of access time windows or the utilisation of reserved road space and parking/loading space for the transport companies participating in the scheme. The latter explains why city terminals are often mentioned in connection with access regulations.

There were some attempts to calculate the environmental and traffic impacts of selected city-logistic measures (CANTIQUE, 2000). According to the surveys (connected to pilot projects) city logistics & fleet and freight management may reduce the emission of different pollutants: CO -0.7%, CO_2 -2.5%, NO_x -1% to -7%, particulate -5% to -8%. Vehicle km can be reduced by 10%, while the volume of traffic can increase and decrease as well (-6% to +1%). Average speed may be higher (+0.7%), and fuel consumption will be more efficient (-1% to -5%). If freight platforms are implemented together with bans on heavy trucks, average speed will decrease (-6.5%), while traffic volume and fuel consumption will be higher (+2.9% and +6.2%). The costs of establishment of freight distribution centres amounted in Germany about 163-769 million € (1995 prices), while with reference to CO_2 emissions the average cost-effectiveness value is about 0.527-1.482 k€ per tonne reduced.

5.1.4 Interactions with other measures

In most countries there are a number of regulatory and financial framework conditions that directly influence (restrict or support) the establishment of urban freight platforms (BESTUFS, 2003).

Legal constraints may set particular requirements to the handling facilities and the distribution conditions for unpacked and temperature sensitive goods. Transhipment of high value products is often prohibited by insurance companies. In some countries the general urban planning regulations for industries regulate the establishment of city logistic terminals. The law may state certain technical and spatial requirements for the establishment of transhipment platforms, secure the locations of existing and possible future industrial areas suitable for logistic platforms by land use plans on a local/regional level. Furthermore a specific study on the environmental impacts may also be required for new transhipment and distribution centres.

It is common that cities apply access restrictions like delivery time windows, vehicle weight limits, lorry bans, etc for the inner city or certain areas. Obviously, these restrictions can favour urban distribution centres if either they can cope better with these restrictions (e.g. by using appropriate vehicles) or if they are given a special status, i.e. if they are (partly) exempted from the restrictions. Urban road pricing (e.g. a cordon pricing) could also influence the establishment of city terminals if it charges different prices structure for different vehicles types. A new logistic centre can take advantage of the distance related heavy vehicle fee which makes intermodal transport more attractive.

To summarise the former analysis, restricting legislation includes:

- urban planning regulations (location, emissions, etc.);
- restrictions for particular goods (bundling, insurance);

and supporting legislation includes:

- governmental (co-)funding;

- city access regulations favouring city terminals;
- road pricing favouring intermodal transport and transport bundling.

It is advisable to use also other, complementary policy instruments to enhance the effectiveness of city logistic infrastructure developments. Some of these can be (Budapest city-logistics project, 2002):

- improving logistic strategies for small and medium sized enterprises. SME-s on the demand side of logistic services in cities have in general no clear logistic strategies. Most of them plan their purchasing and distribution processes on an ad-hoc basis. They are not aware of the advantages – like lower unit costs – of integrated supply chains and the negative effects – like external costs – of congestion. Public organisations, among them local authorities, have to encourage initiatives making possible for SME-s to become familiar with state of the art city-logistic techniques;
- applying geographical information systems (GIS) to give city-logistics an exact planning-organisation basis. GIS based information technology tools support the efficient planning and monitoring of transportation or storing procedures. GIS solutions integrate basic data of goods, vehicles, plans and customers. They offer optimal routes by exploiting the information of integrated database. Moreover, they are able to receive and process also GPS data, so that the current position of vehicle fleet can be incorporated into monitoring facilities as well. Optimisation of goods flows can be carried out not only in the case of transportation, but also in larger warehouses, distribution centres.

Practical experiences emphasise the need of combination of different city freight management measures (CITYFREIGHT, 2002). Urban distribution centres are mentioned among market initiatives as well as among land use & infrastructure instruments. In this respect city logistic terminals have to be regarded as integral parts of measure combinations aiming at increasing co-operation among logistics companies and provide new and improved services in the distribution market on the one hand, and influencing the volume, structure and orientation of goods transport on the other hand.

5.2 City freight management measures

5.2.1 General characteristics

City freight management (or urban logistics) relates to all those activities of organization, administration and supervision of material, related information, and money flows along a supply chain consisting of several companies (suppliers of raw materials, producers, wholesalers, retailers and logistics service providers) and the final customer, which can be a private person, public authority, company or an other organisation.

These activities can be executed only if adequately supported by a certain range of tools and instruments that allow an optimal and effective performance of a city freight management process :

a. IT systems (data collection systems, data transfer and storing systems, management systems);
b. Material handling and transport systems;
c. Traffic route and terminal infrastructures;
d. Administrative environment (legislation, standards, etc).

Urban logistics concerns logistics processes and operations in urban areas, taking into account the operational, market, infrastructure and regulative characteristics of the urban environment. Moreover, urban logistics forms an integral part of interurban and international logistics chains.

Urban freight transport does not only includes the transport of consumer goods, but freight transport in urban areas of industrial goods, waste materials and construction materials as well. In earlier studies, however, urban freight transport was mostly restricted to transport of consumer goods within urban areas. Through-traffic, that is freight transport flows with both its origin and destination outside of the urban area, can play an important role in the problems caused by freight traffic within urban areas. A point of attention is that freight transport is considered to be urban freight transport as soon as it crosses the city borderline. However, many of these transport flows have their origin outside urban areas or within other urban areas. This has to be kept in mind, because it can affect the effectiveness of certain local measures (Visser, van Binsbergen et al. 1999).

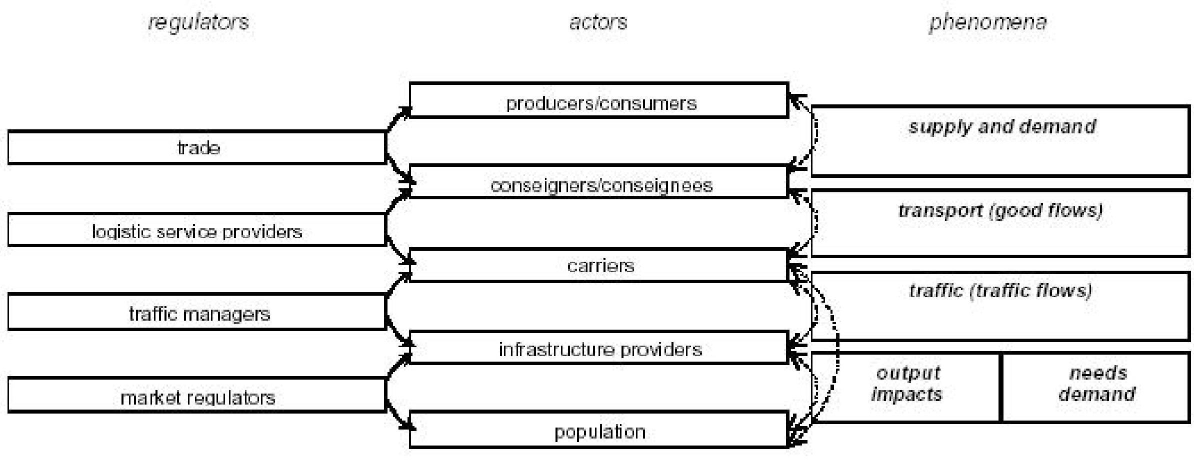
A distinctive feature of the urban freight management is the development of freight centres, this task being part of many national policies regarding freight transport. Freight centres were exhaustively discussed in chapter 5.1.

5.2.2 Implementation actors and processes

Urban freight transport involves a series of numerous and heterogeneous actors:

- transport (haulage) companies
- logistic service providers (LSPs),
- shippers,
- suppliers and trade partners,
- but also governments and the society as a whole.

Moreover, in the field of urban freight transport several types of actors and regulators are involved. The urban freight transport system is a typical multi-layer system. Between the layers there are numerous market-places (indicated as phenomena in the picture below) with supply and demand of services and regulators that organise these markets.



Picture 1: Actors and regulators related to urban freight transport
(taken from Visser, van Binsbergen et al., 1999)

The role of governments is traditionally that of infrastructure provider and regulator and traffic manager. Governments also intervene in other markets when social objectives are at stake, by implementing a certain range of measures and pursuing specific strategies that relate to urban freight transport policy and planning.

5.2.3 Likely impacts

Road freight transport has increased dramatically in the past decades within the urban conglomeration, and prognoses for the future indicates that the growth has not come to an end. The negative aspects of this growth are most visible in all European urban areas: congestion to which lorries and small delivery vehicles contribute, noise emissions, emission of pollutants and accidents are problems that decrease the quality of the urban environment substantially.

In this context, an overall ensemble of policy measures concerning the whole of urban freight management is being increasingly applied. These are exemplified, according to their private and/or public nature, in the table below, where the various measures are classified also according to the type of activity/tool/facility to whom they can be applied:

Table 12: Measures applied in the field of urban freight management

Measures	*Public*			*Private*	*Public and private*	
Applied on	**Licensing and regulations**	**Pricing**	**Financial support**	**Voluntary cooperation**	**Technology improvement**	**Information systems**
Land use	Zoning for logistic activities or transport-intensive retail	Land use pricing	Subsidies for land use prices	Concentrate businesses on one location		
Logistic operation	Minimal load-factor		Subsidising intermodal transport	Load exchange	New load-units	Cargo information systems
Networks	Truck routes, vehicle and time restrictions	Road pricing	New infrastructures for freight		Road construction	Real time traffic information
Terminals	Urban distribution centre		Terminal exploitation	Operation of terminals	Transhipment and storage	
Loading/ Unloading	Loading time	Differentiated parking charges	Facility support	Shared unloading facilities	Off-street unloading facilities	Reservation system of parking lots
Vehicles	Emission standards	Fuel taxes	Subsidies for low emission trucks	Share of vehicle fleet	Electric vehicles, handling equipment	Vehicle tracking systems

Source: Visser, van Binsbergen et al., 1999

The ensemble of these policy actions generally focus on three main categories of desired impacts (CITY FREIGHT, 2001):

- *Improvement of accessibility and circulation*: policies aimed at achieving infrastructure that complies with certain quality demands. Measures can consist of building infrastructure, using infrastructure more efficiently and/or imposing regulation on infrastructure use. What is positive for one traffic sector, however, can work out negatively (speed, flexibility) for other sectors within or outside the traffic and transport world. These days, many debates arise on whether provision of adequate infrastructure can follow demand and what is an “adequate” level of infrastructure.
- *Improvement of environment and safety*: reducing emissions and enhancing the safety of the traffic system. In this case, too, the definition of sustainability, the trade-offs between safety targets, and the impacts of environmental questions on the transport and logistics sector will give rise to debate. Determination of the principles for calculating and internalising the external costs (negative environmental and social impacts) caused by transports has been topical in discussions and studies within the EU.
- *Strengthening of competitive position*: creation of the right conditions to maximise competition of the sector as a whole and to increase the competitiveness of transport companies and logistic service providers. Employment in the logistics sector and its contributions to the GDP and tax returns are dependent on its competitive position. Further, an efficient logistic sector helps to increase the productivity and competitiveness of the whole economy.

The problems of freight transport are, however, still augmenting even if more and more cities are imposing limitations for delivery of shopping centers by heavy vehicles. Time windows for delivery were introduced. Initiatives for urban freight distribution were undertaken. Although most of the developments mentioned above have started only recently (roughly in the last decade), first results can yet be identified. **Moreover, some first results seem counterintuitive: for instance, instead of reducing congestion, some Urban Distribution Centers generate more freight vehicle movements than before** .

One of the main elements in dealing with city logistics trends and developments is the availability of adequate infrastructure. Already, in many cases, the lack of multimodal infrastructure is increasingly becoming a problem. Although alternative freight modalities like inland shipping, rail transport and pipeline transport are providing possibilities to realise a modal shift, providing an excellent road infrastructure will remain of prime importance. With the rise of E-commerce, the digital infrastructure also deserves attention.

Indeed, the increasing use of information and communications technology (ICT) based solutions in logistics is playing a growing role. ICT are deemed useful in the easing of the consolidation of cargoes and in that sense decrease the number of deliveries in urban areas. On the other hand, the ICT will make possible customer tailored (delivery time tailored and product tailored) solutions that actually lead to an increase of deliveries and smaller delivery lots. The e-trade is still mainly trade between companies (B2B). The biggest impacts on city distribution will be generated by business to consumer trade (B2C). The increase of B2C e-trade requires new logistics arrangements also in the city centers, such as space for reception boxes, terminals concentrated on providing logistics operations tailored to the needs of e-trade as well as new traffic arrangements and information services. New arrangements will be a relevant problem especially in the old city centres with narrow streets. In the future, shopping centres and supermarkets will more and more be established in the outskirts of towns and cities. This will decrease cargo traffic in the centre but, on the other hand, increase passenger car traffic and deliveries alongside city centres. Shopping centres with many different shops will also increase the number of deliveries due to lack of logistics co-operation between retailers.

The reports from the three Round Table Meetings on urban freight transport, organised by the European Conference of Ministers of Transport (ECMT, 1976; ECMT, 1984 and ECMT, 1998), presented interesting overviews of current trends and likely impacts of urban freight management. In particular, ECMT Round Table 108 (ECMT, 1998) provided a number of suggestions and insights, namely that:

- The use of heavy, fully loaded goods vehicles rather than a large number of light goods vehicles is far better option. Large numbers of light goods vehicles in traffic flows generate far more CO2 emissions and result in higher levels of congestion.
- The location of freight depots in the center of the city rather than on the periphery is preferable. If depots are located in peripheral areas, the flow of commercial vehicles is added to traffic flows in and out of the city center during peek hours.
- Designated parking spaces for vehicles making deliveries serve no useful purpose since nobody complies with the regulations; they are either used as parking spaces for private cars or they are used by retailers for other purposes. Town planners therefore have to take proper account of delivery interfaces.
- Night deliveries must be encouraged, since such deliveries allow infrastructure to be used more rationally. Advances in vehicle design and technology mean that silent lorries are now available, while loading and unloading areas or centres can also be 'soundproofed'.

5.2.4 Interactions with other measures

Intermodal solutions and especially solutions based on combining passenger and freight traffic have major potential in decreasing inter- and intra-city freight traffic. The usage of new IT solutions makes the combining of intermodal solutions and passenger traffic a very effective means of improving urban logistics (for example small delivery lots / small units in passenger trains and the use of the metro during the night time for deliveries in cities). Local bus traffic could also be used more in freight transportation. Certain products may need tailoring for different customers nearby or within the urban areas (houses, furniture, etc.).

A range of complementary measure that are in the reach of governments to implement in relation to urban freight transport policy and planning includes:

- *Network strategies*: specific routes can be nominated for use by trucks. Truck routes may also be designated only for specific classes of vehicles. For instance the nomination of specific routes for vehicles which exceed statutory mass, height, width or length limits or routes for trucks with hazardous loads. It is also possible to prohibit trucks to use particular routes (route bans), or to enter a designated local area (local or regional area ban);
- *Parking or loading strategies*: there are different types of facilities for parking, loading and unloading: curb-side use, off-street facilities and truck parking facilities;
- *Location and zoning of land use*: for instance, spatial concentrations of transport generating or attracting activities near freight transport facilities;
- *Licensing and regulations*: like traffic regulation, like the allocation of curb space, loading time restrictions, truck route regulations and truck access controls, transport

regulations, like permits for entering certain areas, or vehicle regulations, to regulate vehicle sizes or emissions.
- *Pricing strategies*, namely road pricing or charges on access or parking are ways to let the market mechanism solve traffic congestion.

New strategies, chiefly based on the provision and use of ICT systems and tools that help build a more efficient urban freight management, can be added to the above list, namely:

- *Traffic information systems*: for instance the provision of road traffic information through a vehicle information communication system, or through electronic traffic information boards along the road.
- *ITS (Intelligent Transport System)* : this includes the development of new vehicle control systems.
- *Electronic Toll Collection (ETC)* systems along the toll roads.
- *Logistic information systems* (in-company or between companies). These information systems can be applied within a company to improve the distribution of goods or they can be used between companies, for instance, for co-operative pick-up & delivery or for co-operative operation of terminals.

A source of valuable information is the research work in the field of urban freight transport that was carried out in the period 1994-1998 for the European Commission, within the framework of the COST 321 Action. The final report of this Action concluded that the measures reported in the table below were the most efficient ones to be combined in order to improve city freight transport.

Table 13: Efficient and not efficient measures in the field of urban freight management

Measures	*Promising*	*Less Promising*
Logistics	· transport co-ordination and co-operation between retailers · reduction in package volumes · information systems and systems based on the use of telematics · goods distribution centres · use of urban transport containers/ local service containers · replacement of large trucks or vans · route/tour planning	· service differentiation / reduction of service level requirements · shared use of storage by retailers · promotion of storage facilities in inner urban areas · outsourcing of freight transport · development and use of light goods handling equipment · development of lock chambers common to a group of receivers
Modal choice	· inter-mode transport co-ordination · regional rail network in conjunction with urban distribution centres	· use of bicycle transport for the small or short range transport of retail shops · use of pipelines for transport of fuels and certain types of waste · underground freight manipulation · use of cheaper handling equipment
Price	· truck-ownership licences for urban distribution · road pricing in cities	· parking duty for delivery trucks modulated according time of day, parking time and site · public subsidisation of railway transport in cities
Infrastructure and physical planning	· optimisation of distribution systems including transport centres · geographical bundling or separation of functions · strong expansion of the rail network	· promoting less transport intensive economic activities · extension of transhipment facilities · assignment of industrial/commercial estates to existing/future transport infrastructure · solve infrastructure problems · removal of freight transport depots from

		residential areas · wide lanes to accommodate freight transport · energy conscious road design · to re-value railway or fluvial central urban sites as urban distribution centres · accelerate procedure and direct routes between distribution centres and the inner city
Traffic management	· regulation of freight traffic · guidance and information systems for traffic management	· specific use of infrastructure for goods transport · HGV or truck routes in cities · reservation on streets of special sites for truck stops · speed limits and external speed control · hierarchy in infrastructure for freight transport
Technical measures concerning the vehicle	· use of alternative fuels · harmonisation of load characteristics and units · development of silent vehicles and handling engines: delivery and pick-up during the night	· stopping of engine during goods handling · speed limiters · technical measures concerning the vehicle · electronic devices for fuel use and gear shifting recommendations · regeneration of brake energy
Driver's behaviour		· influencing the driver behaviour
Other measures		· harmonisation of national regulation · search for an optimum sized Urban Delivery Vehicle · to remove obstacles to electronic proof of delivery

Source: adapted from *COST 321 Action* Final Report, 1998, European Commission

6. Intelligent Transport Systems

6.1 General characteristics

ITS (Intelligent Transport Systems) are a group of innovative tools based on information and communications technologies applied in the transport sector (KONSULT, 2003). There are a lot of reasons for implementing ITS in urban areas:

- ITS can give significant benefits on the efficiency, safety and environmental impacts of a city's transport system;
- ITS can lead to cost savings for authorities, operators and users;
- ITS measures can help give the city a modern, high tech image, and improve the quality of life for citizens;
- ITS programme can strengthen the local economy, help business and create new jobs.

The followings describe briefly some of the various ITS tools available and the benefits they offer (Boltze, 2001; CLEOPATRA, 1999; KONSULT, 2003 – based on ERTICO).

An important function of ITS is the on-line monitoring of network conditions and the possibility of reconstructing the traffic patterns of the network from historical data. Collective traffic information and guidance through VMS (Variable Message Signs) technology can help to achieve the objectives of drivers and operators effectively, provided that specific strategies are adopted to implement and select messages and to divert traffic. These strategies must be able to react to traffic problems in real time and to apply network optimisation criteria.

In-vehicle electronic journey planners may guide drivers along their route to any chosen destination, and this is especially useful in an unfamiliar location, where they may provide information and guidance to individual drivers to help them to select an efficient route to their destination. Adding real-time traffic information about current incidents, road works and special events lets drivers change routes and save time. In-vehicle parking information leads drivers to the nearest available parking spaces, and can even allow them to book and pay in advance. Continuous information can be sent through RDS-TMC (Radio Data System – Transport Management Channel) communication links and is an added value for drivers owning the equipment.

Advanced traffic management tools ensure that road network capacity is used to its maximum. For example: Urban Traffic Control (UTC) systems – managing signals – minimising delays and controlling queues; "green wave" through traffic lights for emergency service vehicles, and public transport vehicles priority over other traffic.

Electronic payment, access control and automatic enforcement systems are important and flexible ITS tools for managing a better distribution of traffic in overcrowded networks. Electronic payment systems such as smart cards offer operators more flexible ticketing, lower administrative costs and better marketing information. Passengers save time boarding and alighting, and appreciate the cash-free travel.

Multi-modal information systems may help travellers to plan their journey before leaving home or the office. One telephone call, a quick check on the web site, or even a hand-held terminal can give details of public transport services, including timetables, fares, interconnection as well as current service disruptions. With complete, up-to-the-minute information, people can choose the best way to travel.

Pollution monitoring systems offer cities the opportunity to use traffic management tools to reduce the levels of pollution caused by traffic. Telling drivers about the pollution their vehicles are creating also improved public awareness of the problems.

Journey time is the primary parameter for decisions in transportation, from mode choice to route selection. Journey times in a road network are not constant values; they change subject to traffic demand. Knowledge of journey times and their precise prediction optimise traffic operation by lowering costs and assigning spare capacities. Journey time prediction is a supporting method to all systems of traffic control, in which link or trip journey times can be used as parameters.

ITS tools such as adaptive speed control and camera systems for speed and traffic signal enforcement will increase safety of vulnerable road users, particularly children, elderly people and the disabled.

Some ITS technologies need special equipment and communication networks to be used, such as non-stop payment system on a toll road network. This requires rather substantial new infrastructure cost. Others also require costs to further research and develop a new technology. These estimated costs of the investment will be strongly influenced by both the technical specification and amount of equipment required. It is very difficult to define the technological specification, but the key factors affecting the volume of equipment required are (KONSULT, 2003):

- the geographic coverage required,
- the density of beacons,
- the requirement for gantries on which to mount beacons,
- the design of the centralised architecture,
- the penetration of installation of in-vehicle equipment.

A very detailed database on ITS implementation costs can be found on the related homepage operated by the US Department of Transport (US ITS Homepage, 2003): http://www.benefitcost.its.dot.gov/its/benecost.nsf/ByLink/CostHome.

The costs database contains two types of cost information: unit costs and system costs. Unit cost is the cost associated with an individual ITS element. System cost consists of multiple ITS elements and typically represents the total cost of an ITS project or portion of an ITS project.

Unit cost estimates are categorised as capital and operating & maintenance costs. Capital costs are the cost expended for one-time, non-recurring purchases. Examples include costs of equipment, system design, and development of integration software. Operations and maintenance costs, often referred to as recurring costs, are the costs that are incurred on an ongoing basis. Typical examples include utilities for a traffic operations centre, wire line or wireless monthly fees, and labour costs. Costs are presented in a range to capture the lows and highs of the cost estimates from the different data sources identified. The cost data are useful in developing project cost estimates during the planning process. The system costs database provides examples of systems that have been deployed and includes the cost of the implementation. Note, that these cost data are based on US experiences, so they need to be used carefully when adapting them to special European cases.

6.2 Implementation actors and processes

Public and private participation is a key factor for an effective implementation of ITS (US ITS Implementation Strategy, 1998).

The deployment of ITS needs to be viewed within the context of the overall transport decision-making processes and instruments, including e.g. long range transportation plans, major transportation investment studies, corridor and sub area studies, local transportation improvement programs, congestion management plans and air quality plans.

Private sector funding and technical expertise is also necessary to develop and implement ITS technologies, and to ensure that new transport system infrastructure is properly operated and maintained. Some of the reasons for encouraging private sector involvement in ITS include: ensuring efficiency, raising new sources of capital, shift of risk, market responsiveness, access to special knowledge and/or technology.

Private actors can act as service providers (making capital investments), operators, system integrators, software or telecommunications providers and application developers. The private sector also plays a role in the development of industry standards, that make interoperable systems possible. These industry standards are often developed with a consensus process by the standards developing organisations. These standards may enhance the confidence of the private sector to develop and deploy new products and services.

ITS implementation depends on various sectors of the national economy to produce, operate, maintain and ultimately use ITS services. Successful deployment requires participation by individuals and organisations that are motivated to provide, purchase, and use each of the necessary system elements:

- producers: the private sector plays the principal role in production of ITS systems, and competition is encouraged by market oriented price structures and economies of scale. The public sector’s role is generally limited to provision of data to encourage production and deployment of information. Conversely, the public sector’s role with regard to traffic and emergency management has been, and is likely to remain, very significant;
- operators: the majority of ITS subsystems may be operated either by the public or commercial sector depending on the local situation. The subsystems which provide traffic management, commercial vehicle administration and inspection, and emissions management are assumed to remain largely within the public sector. Information service providers are specifically targeted for the commercial sector, while individuals operate the personal vehicle and personal information access subsystems;
- users: they are defined to be those who derive benefit from the operation of ITS systems. Public agencies (different local authorities) mainly benefit from the operation of a particular subsystem because it enhances the services (e.g. traffic control, emergency, etc.) they provide. The commercial sector users can be categorised as commercial vehicle operators, emergency vehicle operators (e.g., towing companies, private ambulance services), transport service providers (e.g., toll road operators, fleet operators), and special information providers. And there is the general public divided into individuals and the public at large.

The successful deployment of ITS is also based on the requirement that funding for production as well as operation and maintenance is available. Private industry will not participate where a reasonable return cannot be expected. They may, however, participate if incentives are provided by the public sector. These incentives cover a broad spectrum that can include several tools, from tax credits to grants. However, as a general rule, investments in ITS should provide in the long run enough returns to justify private funding.

A number of concerns have been raised about loss of privacy associated with various ITS solutions. This includes concerns over being able to identify vehicles (via network surveillance) and the ability to track movements (via dynamic toll and parking management and fleet management). Privacy concerns are found to create a substantial user acceptance problem. A majority of the public will voluntarily surrender privacy interests if they pragmatically believe that the benefits of the technology are significant and outweigh privacy concerns, and if the data is properly protected.

The main barriers of implementation of ITS can be identified as follows (KONSULT, 2003):

- finance: in many cases, the significant cost of the communication infrastructure would be borne by the application. However, ITS might lead to cost savings for authorities, operators and users in the long term;
- political: there are usually few political barriers to the introduction of ITS. However, some ITS tools might be difficult to accept for users when they need to pay high user charges or buy expensive instruments to use these ITS systems;
- feasibility: sound feasibility studies such as cost benefit analysis and financial analysis are required before introducing ITS and choosing the appropriate technology.

6.3 Likely impacts

The impacts of introducing and applying ITS solutions can be identified as follows (Boltze, 2001; CLEOPATRA, 1999; KONSULT, 2003; Urban mobility project, 2002):

- demand impacts: the demand impacts of ITS depend on the types of implemented fields, but ITS can have a significant impact on all stages of a journey in terms of time required. The large amount of information available to ensure travel planning greatly reduces wasted time. Pre-trip information, for example, enables accurate planning of the most efficient and effective routes as well as appropriate selection of a public transport option through real-time itineraries. In-journey information, such as real-time traffic data and arrival/departure times, increases journey speed and decreases waiting for public transport In addition, drivers also benefit from ITS use in infrastructure, enjoying speedy (and automatic) toll payments as well as variable message signs, ramp metering that warns drivers of potential slowdowns or suggests alternate routes. Fleet operators can also use ITS to streamline delivery times thanks to tracking systems, routing systems, electronic weigh-in-motion and the digital tachograph;
- supply impacts: there will physically be no increase in the supply of road space and public transport service by applying ITS technologies. However, reduced journey times and stop-start conditions, and re-routing into less traffic-congested roads may in practice increase road capacity. Public transport supporting systems such as smart cards also will generate benefits for public transport users. The scale of these impacts is still difficult to judge;
- impact on key policy objectives: ITS have potential to contribute to all of key urban transport policy objectives, but the scale of contribution is dependent on the types of

application. Its main effects include improving efficiency by reducing journey time, improving reliability and utilising less congested roads, promoting local economic growth by freeing up potentially productive time currently wasted in delays, protecting environment by reducing air pollution, making better equity and social inclusion by improving public transport conditions, and enhancing safety by the reduction in the number of road casualties;
- mitigation of adverse impacts: the application of ITS tools can mitigate congestion related unreliability by providing real-time traffic information which facilitates the use of less congested routes and/or the anticipated knowledge of a reliable arrival time to destination. Another positive impact can be the reduction of externalities coming from global warming, and air pollution by reducing stop-start conditions through electronic toll collection system or offering pollution monitoring. Accessibility to public transport can also be improved, which helps mainly those without a car and those with mobility impairments;
- winners and losers: each ITS instrument would generally be introduced to improve specific objectives such as efficiency, environment and safety. This will induce more winners than losers. For example commercial traffic may benefit from reduced journey times and better information on routes or areas used by freight vehicles applying ITS based fleet management systems. Car users may benefit from reduced journey times, increased safety and better information even if some ITS tools are very expensive to use, while public transport users may benefit from the introduction of electronic payment systems or automatic vehicle location systems to guide the bus location.

According to project CANTIQUE (CANTIQUE, 2000) the implementation of ITS measures may result generally in less environment pollution and better traffic conditions. Some surveyed data supporting these conclusions are the followings: CO +0.2%, CO_2 -0.2%, NO_x -0.1% to -6%; average speed +1.1%, fuel consumption -2-3% to -14%. The integration of different ITS and related measures may act also more effectively. E.g. in the case of in-vehicle route guidance/information accompanied by buses and tram control the experienced impacts were the followings: CO -2-4%; traffic volume -9%, travel time -3%. Another example was connecting intelligent traffic control and pre-trip travel information: CO_2 -5.3%, HC -6.1%, NO_x -4.2%; vehicle km -3.5%, traffic volume -4.5%, average speed +3.5%, travel time -7.6%.

Case studies of packages of measures in the field of urban telematic applications have been also evaluated by CANTIQUE. Two different packages were simulated:

1. the first package assumes that current travel demand and any increase in demand will be met chiefly by individual transport modes. In view of this, it is necessary to improve the individual transport system. A number of ITS measures were used to achieve this aim. The backbone of the system was the creation of special traffic routes where traffic flow is optimised and the disturbance from public transport, pedestrians and parking is limited. A policy of maximum penetration of vehicles was used where appropriate;
2. the second package is on the contrary public transport oriented. It is anticipated that some of the current travel will move from cars to the bus/tram system and that the future increase in travel demand will be met by an improved public transport system. ITS measures can assist in different ways. This version has its central focus on an integrated Public Transport system which links buses, trams and park-and-ride schemes.

Costs structure for each package is composed of investment (capital) and maintenance & operation costs. Investment costs were annualised over 30 years using a discount rate of 5%. A summary yearly costs in EUR at 1995 prices follows: site Gothenburg – public 11,700,000 and individual 25,000,000; site Stuttgart – public 31,000,000 and individual 33,000,000.

VMS applications were verified in project CLEOPATRA (CLEOPATRA, 1999): routing and information strategies were evaluated. Guidance recommendations displayed on VMS were perceived useful by 77% of interviewed drivers. 36% of drivers were directly concerned by the displayed destination and 11% of them changed their route the morning of the demonstration survey.
Detailed analyses of the correlation between the diversions suggested by the VMS/VDS and traffic conditions in the road network showed the correctness and reliability of ITS. Driver compliance monitored through extensive roadside interviews was shown to be quite low and seemed to decrease over the course of trial years. After some months of normal system operation drivers showed more confidence in the system: most of them learned new routes according to the time of the day simply by following the suggestions provided by the VMS/VDS panels. Higher levels of driver compliance could be expected if better, more reliable information was provided on the VMS system.
Strategies for in-vehicle information systems (IVIS) were also demonstrated. Trials conducted in the area controlled by the system demonstrated time savings higher than 10% for the equipped vehicles. Interviews with drivers who had used equipped vehicles showed that the system was perceived to be useful and easy to use. 22% of drivers followed suggested routes entirely. Guidance was more likely to be used for unfamiliar journeys.

6.4 Interactions with other measures

For Public Transport users ITS is strongly connected with information provision measures and also with ticketing and tariff systems. For PT operators and planners ITS gives more possibilities for bus prioritisation. The use of ITS helps to balance supply and demand (service level requirements) and helps in operational management. If public and private transport management systems are integrated, synergy can be anticipated. For example in Turin both modes have benefited in terms of travel times, PT share has increased and also environmental benefits have been observed.

Looking at the urban transport in general, the KONSULT database recommends some complementary measures to urban ITS (KONSULT, 2003). For example parking charges and urban road charging may be the solutions to overcome financial barriers: a certain part of the revenues coming from these measures could be contribute to funding technology improvements, in particular when launching the ITS projects.

Other instruments may reinforce the possible benefits of urban ITS. Here urban traffic control systems can be mentioned as using ITS data in the planning and execution of traffic management, and conversely they are updating ITS databases with real-time information. At this regard, successful pilot applications executed in the project CLEOPATRA showed that it is worth integrating the ITS tools with each other and with urban traffic control (UTC) systems. The results of the integrated control strategy impact analysis demonstrated the potential of the control scheme. Trials showed potential savings ranging from 10% to 18% in terms of journey times for drivers able to exploit fully the information on the best routes provided by the control strategy. By increasing the number of drivers able to exploit the best route indication, savings were expected to be around 10% at the network level.

Some related issues have already been considered during the analysis of other physical measures (see e.g. the role of geographical information systems in the operation of city logistics terminals, or the importance of ITS based traffic control systems when realising traffic calming, etc.).

7. Infrastructure provision, maintenance and land use measures

7.1 Road infrastructure expansion

In any particular circumstance, infrastructure is likely to be a necessary prerequisite for an effective transport system, even if it is not always sufficient, without provision of accompanying measures. Tailoring infrastructure to demand and other transport and public policy packages is an important task for any city decision-maker.

7.1.1 General characteristics

The physical context of urban traffic flow is determined by the geographical layout of a city. There are mainly two reasons for considering "expansion of road infrastructure" an important instrument:

1. the main road network is one of the core attributes that determine the functionality of the city: a star-like road network induces high density traffic and concentration of business life in the centre, while circle-shaped road network may induce a rather disperse layout, etc. Therefore, one of the most effective measures is the layout-appearance.
2. building out the city's road network, or providing the enlargement of it is one of the highest public expenditures (next to sewage plant, heating power stations, etc.). Financing of these expenditures has an impact on completely different parts of the citizen's welfare as well, due to the multi-layer (national, regional, local) system of taxes and subsidies usually in place.

Usually, the expansion of road network is needed to tackle with:

- congestion;
- scarcity;
- population dispersion;
- workplace alignment;
- new social centres (hypermarkets, cultural centres);
- development of foreign or domestic tourism, etc.

With regard to congestion, it is known that increased car-use has encouraged the building of the road network and therefore its capacity enlargements. Car-use and capacity of road network increase mutually and therefore follow the same development patterns. This expansion of road is valid for inter-urban roads and for urban roads as well, where road space was often claimed in the past from PT by closing down of PT services or from pedestrians by narrowing of pavements.

Although this measure is very important, we can observe a trend nowadays, which is a backward shift from new road construction to intensive management of urban road networks and improved public transit (DESIRE, 2003). It is getting more and more obvious, that cities cannot build enough road capacity, especially in city centres, to accommodate the growth in travel demand by means of the private vehicle. While recognising that expansion of road networks will be required, especially in rapidly growing cities, it is getting more important to have more intensive management of travel demand, better traffic management techniques to increase the practical capacity of available road space, and more improved urban public transport systems.

Before expanding road capacity several analysis are needed. Cost-benefit analysis has found its way into public projects evaluation, and there is a consolidated tradition of application to transport infrastructure investment analysis (CANTIQUE, 2000). In this case benefits are typically measured in terms of reduced travel time and cost to the user.

When speaking about the costs involved in the expansion of transport facilities, the main items usually considered are construction costs, site costs, and maintenance costs. Construction costs are measured in terms of market prices. Site acquisition involves evaluation of taken property, but this may again be based on fair market value, reflecting the opportunity cost of the land in alternative uses. Finally, maintenance costs are computed partly depending on traffic volume and type (variable costs) and partly independent thereof (fixed costs).

The optimal infrastructure capacity can be planned by using economic models, and by analysing the financing possibilities. It is very important to analyse the cost structure. Whereas short term marginal costs do not consider capacity increases and are related to the costs of additional traffic using the existing infrastructure, long-term marginal costs include the capacity expansion needed to service increased traffic demands. Marginal cost pricing in transportation may generate revenues that can be used to help finance the construction and maintenance of infrastructure.

7.1.2 Implementation actors and processes

We may depict the general layout of responsibilities in road infrastructure provision by answering to the following questions:

- Who has to make the investments?
- Who is responsible for the capacity?
- Where do revenues from charging go to?
- Where does money for investment come from?

Two main groups of financial sources can be identified: those costs, which fall primarily under local jurisdiction and those, which are generally addressed at the national level. Congestion and the negative externalities of road traffic on human living environments are primarily issues dealt by local government agencies at the urban and regional level, as well. In contrast, significant transport infrastructure expansion, maintenance of the most important strategic routes and international responsibility for meeting carbon dioxide reduction targets are the tasks of national government.

Usually there exists a standard categorisation of road, classifying which parts of the network fall under the authority of local, regional or national government. E.g. in Budapest the responsibility of main roads crossing the city belongs to the national government. Sometimes to identify which road belong to which authority may become a real problem. Moreover, rural and urban road classification criteria may overlap. Most notably in the case of urban motorways, geometric design, carriageway alignments and standards follow similar principles to those in rural areas, albeit that design speeds and/or design standards may be lower.

The hierarchy of the decision-making process is represented in the decision levels as well. Important junctions, and over crossings and long sections are usually built only with the financial support of the national government (usually these developments take place only in the suburbs, since there is no place left in the downtown districts). Smaller developments are usually promoted by the local authorities. This is the building of short road sections or the renewal of a certain crossing (partly overlapping with the maintenance activities). The district authorities usually have only very limited sources, and therefore are mainly involved in smaller maintenance tasks.

7.1.3 Likely impacts

The expansion of the road network has several impacts on the traffic. The most important of them is the increase of the available capacity. Beside this, infrastructure provision can affect demand for the different modes of transport, the origins and destinations and hence the accessibility of different locations, and the distribution and volume of flows on different parts of the network. Major transport networks can have a powerful influence on the dispersal of development - both residential and employment development. The proximity to major transport networks may lead to travel patterns characterised by long travel distances and high transport energy consumption. Overall, infrastructure provision has a significant influence on spatial growth patterns, economic performance and sustainability.

The capacity of the existing road network is just one indicator of the performance on the whole network and is in relationship with many others. All these indicators may show a big change after the expansion has been performed, so all these indicators have to be overviewed, in order to have a whole picture about the effects of expansion (TRANSPLUS, 2002):

- *car use*. This can be described by the indicator number of trips made by cars: after expansion, because of the increased capacity, car use is expected to grow. It is worth mentioning that negative effects are expected, namely the parking problems. Especially in big cities, where parking is already a big problem now, and the increased traffic will cause bigger problems in this field;
- *travel speed per trip*. The effect of the expansion and upgrading of the road network is generally an increase in travel speed, expressed in kilometre per hour and per trip, due to the removal of “resistance” or prioritisation of the road network. However, due to speed increase there may be new safety problems;
- *spatial accessibility*. The potential travel distance can be measured with the kilometre radius of a catchment area and the related accessibility to a range of available options, i.e. housing, working, shopping, or leisure activities, may be considered as well.

Expansion of roads is clearly combined with land use effects. New infrastructure can influence the location or building new houses, work places or shopping centres.In particular, land use effects include:

- *residential sprawling*: this can be detected analysing the evolution of population density per specific areas (inner city, suburbs). Urban sprawl is induced by increasing income level, low transport cost and increased spatial accessibility, rising price of land and housing in the inner city, growth of living and housing standards, increasing desire to live in a green-field area, etc.;
- *retail centres*: whenever spatial accessibility increases, retail centres require bigger catchment areas. This can be achieved by simply relocating the shop in an out-of-town

area to enable also the access from other towns and settlements. This dependency increases further with increased size of floor space per retail centre on the one hand, and with increasing number of retail centres on the other.

- *work places*: the development of work places and companies follow a similar pattern as retail centres. According to the growth policies of companies, expansion can be realised cheaper on the cities' outskirts. Since there are rarely available PT facilities, employees have no other option than the car to commute to the office or work place;
- *leisure centres*: this follows in the chain of land-use development, since shopping is now combined with leisure activities and therefore increase also in their numbers;
- *travel distance*: an increasing average travel distance, usually measured in kilometre per trip, is a direct consequence of urban sprawl, together with an increased car use.

Thus, new infrastructure will probably cause additional traffic by encouraging car use. This fact can be illustrated by analysing the effect of the biggest road expansion in Budapest made in 1995, namely the building of the 8th Danube bridge (so called Lagymanyosi bridge). Table 14 shows the traffic volumes of bridges, which are listed from north to south.

On the north part, the traffic of the bridges did not increase highly, because they were already fully utilised in 1993. When implementing the new bridge the big boulevard of Budapest was closed on the Pest side, so there was a change in traffic. That means, that the traffic from the other bridge Petofi, which closes the small ring of the city, partly moved to the new bridge. This new traffic grew soon up to the average level of the other bridges.

Table 14: Traffic of the Danube bridges in Budapest in 1993 and in 1996, in unit car/day

Bridge	*1993*	*1996*	*change in %*
Arpad	123 200	129 500	105
Margit	72 700	78 800	108
Chain Bridge	29 800	28 300	95
Erzsebet	92 800	91 400	98
Szabadsag	27 600	30 400	110
Petofi	103 500	82 100	79
Lagymanyosi	0	63 800	-
M0 bridge	45 900	58 500	127
Total	495 500	562 800	114

Source: Urban mobility project, 2002

This investment had other effects, too, namely that the areas along the boulevard, especially near to the new bridge, became more expensive. New houses, shopping centres have been built on both sides of the Danube, which areas were before empty. So not only the road network, but also the scope of city centre have been extended.

Many other examples may be found in the literature showing similar impacts of large road infrastructure on transport flows and land use values, in the cities of Europe and elsewhere.

7.1.4 Interactions with other measures

Road expansion have to be dealt very carefully and must be harmonised with other measures. Their main objective remains to avoid congestion and influence traffic. However, due to the increased capacity and speed the level of traffic will be higher, which can cause negative environmental and safety impacts which require in turn additional measures to be avoided or mitigated. For example dedicated lanes and traffic calming facilities may help, but at the same time they will reduce the capacity of the network.

Whenever planning for significant road expansion, land use and transport policy objectives must be harmonised in order to avoid wrong transport influence. At this regard, there is a range of modelling tools available to assist urban policy makers in their decision-making process. They range from very detailed local models of road and junction layouts to models that take explicit account of the interaction between transport and land use. There are many investment issues addressed by urban planners that do not require the whole scale of land-use and transport modelling, and it would be quite unreasonable and unnecessary to do so. However, integrated land use and transport models are required to tackle with large scale changes in infrastructure, which affect significantly accessibility and mobility for large numbers of people and may cause some changes in land use, as people change jobs, or in the longer term their homes, to take advantage of new accessibility (TRANSPLUS, 2002).

Often complementary economic instruments – like access or parking pricing – have to be implemented so that the increased revenues could finance capacity expansion. The revenue can come from fuel taxes, too, and therefore it has a relationship with interurban measures. Obviously whether the new infrastructure will be priced or not is an important question for project financing purposes. But a more subtle and often underestimated relationship is that between the current infrastructure policy and the present and future road pricing policy. Capacity expansion which is justified in the case of the current transport prices, may no longer be justified with better transport prices which include congestion and other external costs, leading to a more rational use of the existing capacity and a reduced need of new capacity.

In any case, capacity increase can usually be achieved not only by expanding the road network, but it requires better traffic organisation and shifting freight traffic to more effective transport solutions – like intermodal transport. This shift needs using other measures, especially pricing or access regulation instruments.
Furthermore, the building of new transport infrastructures give a wide range of possibilities for introducing other measures as well. Sometimes new infrastructure might have a role of providing a supplementary tool for the implementation process of other transport measures: a typical case is the introduction of road pricing. Firstly it can be implemented at a new road section or bridge, and afterwards the application can be extended for already available infrastructure parts.

7.2 Road infrastructure maintenance

7.2.1 General characteristics

Infrastructure maintenance is usually not treated as a transport policy instrument. The reason is that the maintenance (and the accompanying road clearing activities) are regarded as necessary tasks to keep the transport system running. However, there are some important characteristics of urban road maintenance and clearing that can underline their separate treatment as instruments. Some of these are:

- road maintenance activities have a very strong and special effect to the urban traffic flow. If a section of the road is under maintenance works, some undesired results can arise: congestion in the surrounding sections, increased possibility of accidents, reduced capacity, time loss, increased air pollution, etc.;
- the proper arrangement of road maintenance and clearing activities is a question of traffic flow optimisation. In this context road sections under maintenance or construction behave similarly like other physical measures. The right placement and planning of these activities can enable a relatively undisturbed road traffic in urban areas, while the block headed closure of certain sections or crossings can result in huge traffic congestion;
- the sequence of the maintenance tasks have special importance, if there is a limited source of maintenance capital. The traffic flow can be influenced through leaving a certain road part not maintained or allocating public funds to the improvement of that part. This is why the behaviour of the instrument “maintenance” can be especially interesting for the accession countries;
- road clearing in urban areas are of primary importance in Nordic and other countries, where a strong continental weather can be observed. The snow-clearing priorities can have the same effects as the primary traffic regulation instrument.

After having underlined the rationale for considering road maintenance and clearing as a separate measure, we may define the measure “road maintenance and clearing priorities” as the *systematic and optimised planning of the maintenance and clearing activities in order to minimise traffic impacts, disturbance and external costs*.

The urban road network can be regarded a common public asset that has a certain technical availability. For instance, in Budapest, Hungary the planned lifetime of the reconstructed or newly built road infrastructure parts is 15 years. This means, that (if we can assume continuous maintenance in order to keep the asset value nearly constant, and if the construction takes a half-year time) about 3.33% of all road parts are under maintenance at a time. From an other viewpoint this is equal to the assumption, that the available road space in the city is only 96.67% of those that one can see on the map (because of the maintenance works). These assumptions are close to the reality and underline the importance of the integrated treatment of maintenance activities to facilitate the proper availability over time of road infrastructure parts.

Similarly, during the winter season in Nordic and in continental cities there can occur strong disturbances because of the weather. The snow-clearing activities behave similarly to new infrastructure construction, with the exception that they act upon a very short time scale: it is obviously much easier and rapid to clean a road part than to build it. Those decision-makers or authorities that can decide about the clearing priorities - in what order the roads have to be eased from the snow load - have very strong influence to the overall welfare level in the city. The proper operation of this decision-making system affects strongly the behaviour and welfare level of citizens. In some cases, if there is a lack of financial sources and technical equipment, the time interval of snow-clearing operations can be elapsed over longer periods.

Beside the problem of urban snow, road clearing involves a lot of activities that make streets liveable, have impact on their capacity and the possibilities of vehicles using them. Such activities are: handling the grass along the streets, clearing the road-banks, clearing drains, etc. These can be regarded as the snow-clearing instrument above, with the difference that they do not have such a strong effect on the traffic flow within a short period of time.

7.2.2 Implementation actors and processes

The case study of TRANSPLUS (TRANSPLUS, 2002) for Belgium ranged maintenance works into the group of the competency of the regions (among other tasks like safety equipment, noise abatement infrastructure, etc.). This is similar to the Italian case, where it belongs to the competency of the regions and communes. The situation is similar in other EU Member States and candidate countries, too. Usually there are also some roads in the urban environment that are part of the national road network and/or motorway network.

The "lowest priority" have the so called district-level roads. All the 23 separate districts in Budapest have a quite long by-street-network with relatively low importance. These have to be maintained and cleared by district / neighbourhood authorities (and in some cases even by the inhabitants of the street as well).

This ownership-order poses liability issues as well, related to the technical and/or personal damages or casualties associated with accidents provoked by damaged road section, inappropriate signalling etc. The interested parties in the road maintenance activities are of a broad spectrum. The activities and financial position of these actors are sometimes strongly determined by the following parameters:

- difference between the gross and net value of urban roads;
- earlier road construction technology and planning;
- weather specialities;
- development level and heritage value of the city;
- motorisation level in the city;
- PT market share within the city;
- occurrence of HOV-s: the geographical layout of logistic terminals, high capacity bridges, railway features, surrounding town structure, etc.

For instance, in the case of Hungary the main stakeholders are as follows:
- the central government/parliament: when deciding about the central budget, usually the national road maintenance budget is one of the key element in the next year's central decision making;
- the Ministry of Economics and Transportation: it has the tasks of maintaining and clearing the interurban road network, together with the urban parts of this network. Furthermore the ministry is the subscriber for large infrastructure maintenance projects;
- the Central Authority Board of Budapest: this is the largest source of maintenance and clearing capital. It takes care on the mostly congested routes of the city and some of the over-crossings as well. It employs a dedicates organisation that has the task to plan and to optimise the maintenance tasks both from the viewpoint of the traffic flow and the technical possibilities/capabilities;
- large and small road-builder companies: their activities and financial capabilities are strictly regulated in the contract that has come to power between them and the local/central authority. Large road and bridge builder companies are mainly in contact with the high level authorities, while smaller ones are waiting for district orders;
- Budapest Public Places Handling Limited: with the task to carry out nearly all clearing tasks, it has to keep over the desire amount of snow-scraper, and other clearing facilities with all their technical, institutional and human background;

- inhabitants, businesses, etc: the users of the transport infrastructure and other facilities can experience a well-managed street network or a network with failures on the planning of road maintenance and clearing.

As seen in the example above, more or less nearly all inhabitants and businesses may be affected by the proper working of the road maintenance and clearing tasks of the city. The "graze factor" is much higher if a city is large or has only a small amount of high capacity crossing and/or escape routes.

7.2.3 Likely impacts

Unlike other research projects, the KONSULT database (KONSULT, 2003) mentions the infrastructure maintenance activities as a separate instrument. Indeed, under the instruments for "management of the infrastructure" the first component is "road maintenance" that underlines its importance in the policy making. This belong also to the group of "measures to influence car use", while the maintenance of existing fixed infrastructure is the core part of the group "measures to influence public transport use".

The effects on the traffic flow can vary according to the different tasks and their execution. The impacts are similar to those ones of traffic calming facilities, but with pretty different acceptability and time interval. The following table illustrates the different technical disturbance types and their effects to the road traffic flow (these results are based on Hungarian empirical experiences and are coming from interviews performed among relevant experts).

Table 14: The different types of road maintenance and clearing disturbances and their impacts

Description of the maintenance activity	Congestion (additional time loss)	Accident increase	Other route change	Traffic redistribution in the neighbour streets	Capacity loss	Acceptability (1: worst, 5: best)
Half way closure on a short section (several metres)	4	5	2	2	3	2
Halfway closure on a long section (more than 50 metres)	5	3	4	4	4	4
Full way closure	2	1	5	5	5	5
Temporary bad quality surface (halfway)	3	2	2	3	2	1
Temporary bad quality surface (full way)	4	3	2	2	3	1
Temporary bad quality surface on a long section	4	2	4	4	4	3
Snow-sweeper vehicle	2	1	1	1	3	1
Watering-cart	1	4	1	1	3	1
Road-cleaner workers group	2	3	2	2	4	1

1: weakest, 5: strongest impact level

Source: interviews

The extents and seriousness of the impacts are changing with time: at the beginning the disturbance level can be very high, if drivers experience unexpected changes within the actual lane or route. After some days (as drivers get used to the changes) the disturbance level sinks, and reaches its minimum. Over a certain period of time (normally 1 week) the effect tend to change: the traffic flow try to adapt: some drivers who have the possibility for this will change an other route, and the redistribution of the traffic happens. This redistribution and long term effects, of course, are not true for the road clearing activities, as far as they are only concentrated in short time period. But the clearing activities can cause serious short-term effects, and this legitimates their recording into the table above.

Table 14 does not take this discussion of time implications into account, only focuses on the main types of the impacts. However, some figures of the table may need further explanations as follows:

- a longer section half-way closure (on 1+1 lane bi-directional road) can cause very serious congestion, because in these cases the drivers have to wait for the oncoming traffic. If it is a long closed section, the bi-directional traffic should be ensured by an alternating stoplight that reduces the capacity of the road to the 30% of the original one;
- full way closures are causing usually less congestion than half-way ones (only if the closure is signed attentive before). The reason is that drivers can select another way instead of the closed route, but at half-way closures the "illusion" remains that the traffic might be undisturbed;
- watering-carts can become very dangerous and can cause accidents because of the slippery roads (especially, if it works in a dry environment), and drivers have no time for breaking before the wet surface;
- although road cleaning activities might reach the disturbance level of other maintenance activities, their acceptance in the public is much better. The reason is that the primary result of the road cleaning always serves the needs of the drivers, while road breaking are always “suspicious” (e.g. it can serve some new cable changing, new water pipes or other “off-traffic” needs).

7.2.4 Interactions with other measures

The instrument “road maintenance and clearing” is in close connection with other measures that affect the traffic flow within a city. The interaction is usually evaluated “ex post”, since the maintenance activities are rarely combined intentionally and “ex-ante” with other transport measures.

Project AFFORD (AFFORD, 2001) classifies the maintenance activities and their level among those parameters that should influence the prices in the first-best case (pure economic equilibrium). In this aspect the maintenance does not mean a separate instrument, but one of those that work as a sub-variable for pricing (economic) measures, especially when the investment and maintenance costs are both high. The project carries this point further, and examines maintenance activities in more case studies.

Within project CANTIQUE (CANTIQUE, 2000) the co-operation of some measures were examined as well. For example, increasing the payload for high duty vehicles will reduce the costs of the forwarders, but increase the disbursements of the infrastructure maintainer. An increase of the payload will lower maintenance costs because of vehicle km reduced. At the same time, the increased weight of vehicles will cause additional costs. These opposing effects are regarded to cancel each other out. A partially similar conclusion is drawn in project IMPRINT (IMPRINT-EUROPE, 2003). The cost structure for rail and road follows a parallel pattern: low standard networks are characterised by higher marginal maintenance costs while high standard networks by lower marginal maintenance costs; the thicker pavement on high standard roads and the higher quality tracks on high standard railways tend to be less subject to wear and tear, and hence require less maintenance, than do the pavements and tracks on low standard networks.

Finally, road maintenance activities often influence the on-street parking possibilities and the available space for parking purposes.

7.3 Land use measures

This chapter will appraise and describe two pivotal measures, namely the organisation of the land use mix (development mix), and the integration of broader environmental considerations into transport planning (landscape planning).

7.3.1 Development mix

7.3.1.1 General characteristics

Increasing development densities or organising the mix of land use types to encourage less personal motorised travel is the main objective of these types of measures. As the density of development increases, the average trip length, the use of the car, and the distance travelled all reduce (Banister, 1999). Density refers to the number of people or jobs in a given area. How land uses are arranged in relation to others are referred to as mix. The mixing of land-uses affects the physical separation of activities, which is therefore a determinant of travel demand (Hall and Marshall, 2002). By involving land use and transport planning for new developments and the management of existing land use it hopes to create a shorter distance between origins and destinations.

Land use and transport are interlinked. Where new land uses occur there will be a travel demand to reach these destinations, which will require new infrastructure building (Marshall & Lamrani, 2003). If these new land uses are located at the edge of an urban area, this can create sprawl. Land use planning in recent years is starting to favour an urban area, which limits sprawl for a high density mixed land use. By concentrating urban planning around a polycentric urban structure, a high-density development mix can be achieved. This involves urban renewal in the urban centres and limiting urban sprawl at the fringes, with improved integrated public transport systems to the urban sub-centres.

The evidence from previous case studies suggests that there is a “U-shaped” distribution with respect to settlement size and trip length. A medium sized city will have the shortest trip lengths with rural and very large centralised settlements (Marshall & Lamrani, 2003). Large settlements such as London in the UK attract workers from long distances away. Banister (1999) suggests that a minimum threshold for sustainable settlement size should be 25,000 people or 10,000 dwellings.

From a variety of case study cities found in various research projects including LEDA, TRANSPLUS and PROSPECTS it appears that this regulatory instrument is being adopted but with varying levels of implementation. In countries such as the Netherlands and Germany this instrument has been implemented fully with the ABC Location policy and VINEX in The Hague and the Messestadt Riem and Postdam-Kirchsteigfeld projects in Germany.

The ABC location policy in the Netherlands is a good example of traffic and transport related land use measures that concern companies and services. ABC takes it's name from the designation of city zones as "A", "B" or "C" which define the maximum number of parking places allowed:

- an A-location has high quality public transport and limited car access (1 parking place for every 10 employees)
- a B-location has good public transport and good car access (1 parking place to every 5 employees)
- a C-location has little public transport and allows 1 parking place for every 2 employees

The ABC location policy was implemented from 1990 onwards (LEDA). VINEX and "Getting the Business in the right place" focuses on the lateral aspects of the ABC location policy, in particular the co-operation between cities and the transport links between offices and newly established neighbourhoods. It concentrates on the optimisation of land use, relative to public transport supply and the demand for car use.

The overall aims of this policy are to integrate environmental and accessibility considerations within a spatial planning policy, and to increase the public transport market share and reducing car dependence for home-to-work journeys. This measure hopes to achieve these aims by concentrating on optimisation of land use, relative to public transport supply and car use demand. The ABC policy links in to the VINEX because it directly influences the provision and the accessibility of offices by public transport. The VINEX location was first implemented from 1995 (LEDA).

Many cities apply a form of the ABC policy, in that they encourage stakeholders to a high quality 'place to be' by discouraging with regulatory, legal or financial tools away from 'wrong' locations. Housing programs around existing transport corridors (especially social housing) have also been adopted, (Marshall and Lamrani, 2003). Vienna have combined high density housing with an upgrading of the city rail lines around Eastern-Donaustadt.

The City of Vancouver and the Greater Vancouver Regional District are also using their land use management plans to minimise transport and utility costs for industrial and commercial location. They have a policy of "planning by proximity". Employment densities in Vancouver are three times higher than in the suburbs. About two thirds of industrial employees living in Vancouver also have jobs located within the city, (www.movingtheeconomy.ca).

The Messestadt Riem is a development at the edge of the built up area in Munich with the concept for reducing travelling distances. The core is the Munich trade fair which opened in 1998. It was also honoured at the 17th International Making Cities Liveable Conference (1995) for succeeding in sustainable town planning (Noel, 1999).

To encourage more sustainable travel patterns and less car use planners can use their control to guide the form of development they require. This is easier to do in a newly planned area. Mixed land use needs to encourage a balance of homes, shops and workplaces, (Marshall & Lamrani, 2003). In Tübingen Sudstadt they are reusing a military residential area to develop a mostly independent district. They hope to mix residential, commercial and social facilities for new inhabitants. This is still being implemented. On a former industrial site in Vienna they have created the "Gasometer city" offering a function mix of housing, working, shopping, culture and entertainment. For approximately 3,000 individuals, the gasometer city is on their frontdoor, (TRANSPLUS Deliverable 3)

It is not just within Europe that land use planning is going through a change. Within some cities in North America, "Smart Growth" and "New Urbanism" are being implemented as land use management policies. Smart Growth is a term for policies that integrate transportation and land use decisions, by encouraging more development within existing urban areas where additional growth is desirable, and discouraging low density, car dependent development at the urban fringe. New Urbanism is a set of development practices to create more attractive and efficient communities (TMD Encyclopaedia, Victoria Transport Policy Institute).

The main practises of Smart Growths are encouraging cluster development and activities, reform tax and utility rates to encourage economic development in these infill locations and develop a mix of housing types and prices. The Main Practises of New Urbanism are well-designed, sustainable communities with interconnected networks of streets and compatible land use mix. This is backed up by the thought that a "people-friendly" locality will encourage walking (Marshall & Lamrani, 2003)[21]. Major roads form the spine of neighbourhoods rather than the edges, with roads designed to accommodate all modes of travel (TMD Encyclopaedia, Victoria Transport Policy Institute).

With regard to costs, land use instruments are one of the most costly policy instruments that can be implemented. The cost usually falls to the private sector through investments, developers and occupiers. Local authorities also bear some additional indirect costs such as the provision of extra traffic controls, parking and public transport interchanges, (KonSULT).

"Getting the business in the right place" and VINEX location policies rely on the necessary transport infrastructure being built in advance so it makes sense to integrate the costs within the price of the houses.

Smart Growth and New Urbanism costs include the additional expenses associated with more detailed planning, design and amenities, and extra development costs associated with construction within existing urban areas (TMD Encyclopaedia, Victoria Transport Policy Institute).

Operational costs can be quite high and residents that are encouraged to use public transport, as is the case with VINEX locations can have some of these costs incorporated in the cost of the houses. This means that they will have to pay higher house prices but they will get a better quality public transport system.

[21] see also the discussion of pedestrian-friendly site development in Sect. 4.2.2. of this deliverable.

7.3.1.2 Implementation actors and processes

To make a location policy work it requires the implementation of other transport and land use policies. A location policy can only work well when it is part of a balanced package. Adequate public transport facilities are one of the most problematic issues when implementing a housing policy. The problem of delays may be averted with the inclusion of public transport companies at an early stage in the planning which happens with the VINEX. Public participation and good information provision were two key elements in “getting the business in the right place”

If there is no legislation in place it can make implementation difficult. Countries or cities where there is some form of binding land use planning on a regional level such as the Netherlands and Germany use land use policies to achieve transport goals. There is a national rule for integrated land use and transport planning for the new location of companies in the Netherlands – the above mentioned ABC policy. For most other European countries this ABC location policy is taken into account, but actually implemented without the co-ordination of the national government. Therefore it is expected that additional institutional innovations are needed, similar to the current decentralisation efforts made in the Netherlands. Local authorities in the Netherlands designate the A, B and C zones in their area. This ability to grant planning permission enables the municipalities to enforce this measure.

The LEDA project found that there were large variations in the legal, financial and administrative powers granted to city authorities. In UK cities, they are subject to comparatively tight control from central government, whereas Swiss and Scandinavian communities have greater autonomy.

The integration of transport and land use planning is established in the legally binding development plan of Messestadt Riem. The Tübingen Sudstadt project also has the support of the Federal Ministry of Transport (Noel, 1999)

Within the state of Maryland they have passed “Priority Funding Areas” legislation in 1997. The intention is to facilitate the reuse of brownfield sites and provide tax credits to businesses creating jobs in a Priority Funding Area. A new “Live Near Your Work” program supports this effort by providing cash contributions to workers buying in certain older neighbourhoods (www.op.state.md.us/smartgrowth).

Land use and transport planning integration tends to be more successful in future settlements, while their implementation in older cities can cause problems because of the global approach of the policy. Moreover, depending on where a countries transport and land use investment comes from influences how successful the implementation of this measure is. Unless developers can be persuaded to pay in some way for these developments they can be a large barrier to implementation. An example of good practice in this respect is provided again by the VINEX and “getting the business in the right place” policy in the Netherlands, where the national law on the infrastructure fund (1994) guarantees a long-term policy. The largest financial contribution comes from the central authority, which had pressure placed on them by the municipality because without this investment the project was at risk. There infrastructure finances fit within the national policy to improve accessibility of new building locations.

Land use policies take a long time to plan, implement, and require the cooperation of a number of stakeholders including the regional governments, transport operator as well as the local community.

It appears that stakeholders are more accepting of a project if they are involved and informed from as near to the beginning as possible. With the ABC location policy the public transport operator HTM were involved from the beginning and they are seeing the initial losses as an investment because of the future contracts this policy will bring.

Within North America there have been local as well as professional barriers in implementing Smart Growth policies. Local residents oppose a high density, mixed use development, fearing congestion increases, and parking problems. If new developments can be implemented with measures that reduce per capita vehicle use, and which benefit existing residents most of the opposition can be overcome (TMD Encyclopaedia, Victoria Transport Policy Institute).

<u>7.3.1.3 Likely impacts</u>

There are ranges of policy measures that are available to influence travel demand of which land use measures are one. Land use planning measures can take a long time to take effect, meaning this is not a short-term policy instrument, which in turn can take a long time to see any significant results (Marshall & Lamrani, 2003, and KonSULT). Marshall and Lamrani (2003) state that the rate of turn over of the urban fabric involving the conversion of existing building stock and neighbourhoods takes place at a slow rate, typically 1% per year. Land use planning measures on the other hand can have an influence for generations to come.

Land use patterns affect travel behaviour and it is hoped that higher densities and a better density mix of residential and commercial developments may encourage shorted journeys and persuade more people to use public transport for these shorter journeys. By concentrating these developments around transport corridors it makes it easier to provide a viable alternative to the private car.

KonSULT states that density and mix can have significant impacts on travel demand and travel patterns through the following mechanisms:

- Accessibility: the number of potential destinations located within a geographical area tends to increase with population and employment density, reducing travel distances and the need for private travel.
- Transport choice: increased density tends to increase the number of transport options available in an area due to economies of scale. Higher density areas tend to have better pedestrian and bicycle facilities and better public transport because they become cost effective.

It is also noted that the amount of reduction of motorised travel in response to land use measures will depend on the scale of the land use change, the design and type of change and the speed with which the changes are effected (KonSULT). A study in North American suburb sited in the online TDM Encyclopaedia found that the elasticity of transit mode split with respect to land use density to be +0.10 to +0.51, depending on the land use. This means that each 1% increase in density increases public transport use by 0.1-0.51%.

KonSULT have also noted a study by Ewing and Cervero within TDM Encyclopaedia (2002) that calculated that a reduction of 5% per capita car travel could be achieved by doubling neighbourhood density. A 5% reduction per capita in car travel can also be achieved by doubling land use mix or improving land use design to support alternative modes.

Van and Senior (2000) conclude that mixed land uses encourage walking and cycling, and deter car use, for light food shopping. However, they cast doubt on the strength, and even the existence, of impacts of land use diversity on travel behaviour in general. This is backed up by the findings of Stead and Marshall (2001) state that higher density is generally associated with increased proportion of shopping trips by public transport and increased commuting trips on foot.

The ABC Location policy has shown an increase in bus speeds, thereby reducing journey times for the passengers and the shift in modal split from car to bus. This is a new town and therefore it may be difficult to achieve the same reductions and changes in an existing town or city.

Simmonds and Coombe (2000) have suggested that after testing a variety of settlement scenarios and land use changes and modelling their effect on the transport system that the overall reductions in travel would be small. They also found a limited impact of the compact city, when testing the transport consequences of one or more compact city scenarios reflecting the continuation of recent changes in land use distribution (1990-2015). It resulted in a virtually unchanged volume of traffic but concentrated around the centre. This would indicate that other restrictive measures would be required to limit this concentration of traffic, such as parking charges.

The PROSPECTS study found little evidence of the scale of the effects of density as did the reported German evidence (Marshall and Lamrani, 2003). Kagermier's findings stated in Wegener and Furst (1999) found that spatial scale and distances between city centres and secondary centres were more important.

Smart Growth policies have also come in for some criticism (Eppli and Tu 2000) with the debate focussing on the argument that they provide little real benefits, increase congestion and exposure to noise and air pollution, making residents worse off. There is some truth in the local congestion increase, but Smart Growth advises that parking measures and increased public transport would need to be implemented to counter act the increased concentration of motorised traffic.

The Victoria Transport Policy Institute report that residents in well designed New Urbanist neighbourhoods with good walk ability, mixed land use, connected streets and local services tend to drive 20-35% less than residents in car dependent areas. It is also thought that with the introduction of parking measures and car sharing these figures could be even higher.

As concerns the relevance and measurability of effects and behavioural responses some topical elements concerning development mix measures can be found in the table below.

Table 15: Relevance and measurability of effects and behavioural responses in the framework of development mix measures

Effects:	***Likely relevance***	***Modelling capability***
Capacity/congestion	Relevant – offices and residential areas close by will hopefully means less need to use car and so reduce congestion.	Relevant
Direct user costs	Relevant – could be high in the beginning.	
Reliability of journey	Relevant – if there is greater public transport provision then a more reliable journey on that mode. Less cars could also increase reliability of journey for those that still use the car.	
Quality of journey	Low Relevance – Upgraded public transport will make the quality better. For car users no effect.	
Information provision	Not Relevant	
Environmental effects	Relevant – if more people use public transport or non-motorised means will help the environment.	Relevant
Traffic accidents	Relevant – a reduction in cars should equal less accidents.	
Health effects	Relevant – reduction in motor traffic - less pollution	
Liveable streets and neighbourhoods	Relevant – will reduce the amount of motor traffic and make the areas more liveable.	
Implications for government budgets	Relevant – could be high costs initially in getting businesses to develop in these locations.	
Equity and social inclusion	Relevant – viable public transport and a greater mix of destinations closer by	
Economic growth	Relevant – a more attractive place with increase economic growth.	
Change of location	Relevant – businesses could be attracted by the close proximity of a work force if residential areas also included in the mix.	
Change of private vehicles ownership	Relevant – if there is a more reliable public transport system people may switch from their cars.	
Change of PT season subscription	Relevant – if the service is of a high standard it could increase.	
Change of trip frequency	Relevant – higher densities and more mixed land use bring more destinations within easier reach.	
Change of travel destination	Low relevance – people will still need to visit a certain number of destinations they will just be closer.	
Change of travel mode	Relevant – change of mode to public transport may occur where it land use mix makes it a viable option.	
Change of travel departure time	Low Relevant – it may change if residents work in the new businesses located there.	
Change of route	Low Relevance – will only change if new infrastructure is built.	
Change of driving pattern	Low Relevance – will only change if people switch to public transport.	

Marshall and Lamrani, (2003) found that basic transportation models imply a relationship between land use and travel, but only 25% of policy measures available could be properly modelled by current techniques. They also state that modelling results do not find much significant impact of density on travel as such. They do suggest that density could assist or be compatible with a package of transport and land use measures, even if insufficient on its own. For case study modelling within SPECTRUM it implies that the land use measures chosen to model will be those that are feasible with the models capabilities and possibly not the measures that would be of most interest.

More in general, Marshall and Lamrani, 2003 have also found that although the general themes of land use planning measures are well known the robustness of results are not necessarily consistent, and the exact extent of cause and effect is not conclusive. There are individual factors which make the same land use measure a success in one city but not in others. They consider the fact that it is difficult to evaluate the implications of one kind of planning over another by empirical means for a particular locality at a particular time. It is possible to model relationships, but to an extent, these are dependent upon the inputs and assumptions within the models.

There is also the need to be cautious when drawing policy conclusions with cities of a certain size. If they develop over their 'optimum' size the current policies make create satellite town and increase the trip distances. Combining densification and settlement size could help in keeping travel distances down (Marshall and Lamrani, 2003).

In conclusion, mixed use development can have the potential to reduce travel distances, but it all depends on the behaviour of people using their local shops and not using their cars to reach out of town shops.

7.3.1.4 Interactions with other measures

Marshall and Lamrani, 2003 state that a combination of complementary land use measures can provide an integrated package where each element reinforces each other to achieve a more sustainable town. PROSPECTS report that within the responses from the cities questioned, the measures like parking charges and smart growth (discussed below) can be complementary to density mix land use planning. Restrictions in parking supply and the increase in charges can have a positive effect on reducing increased congestion that could possibly be a result of high-density development mix.

Negative effects can be felt by some land use measures. The high parking charges in the "A" zone of the ABC policy have had a negative effect making it more attractive to visit out-of-town shopping centres (Marshall & Lamrani, 2003).

The ABC Location Policy places emphasise on reducing the number of parking slots required in different parts of the city. This in turn is linked to increasing public transport provision and quality. A new business will only locate to a place it knows its worker can get to easily and if there is no parking available then they will rely on the public transport network. Marshall and Lamrani (2003) point out that the proportion of income spent on travel by households or employees can be reduced if the locations of activities are connected to the public transport network.

The impacts of Smart Growth also tend to be synergistic in that they should all work together to create a higher density of activities and thus reduce the need to use the car.

7.3.2 Landscape compatibility

7.3.2.1 General characteristics

Environmental, social and health impact assessments of transport-related projects, plans and activities are preventive tools for integrating broader considerations into transport planning. Landscape compatibility concerns must be integrated in the early phases of the infrastructure planning process.[22]

The construction or adaptation of infrastructure has often a strained relationship with care for quality of life. The mutual coherence and interaction of social interests make it necessary to explore possible solutions beforehand, to determine the effects and to define a coherent vision. For this purpose EIA-studies, planning studies and strategy studies are carried out.[23]

The disciplines of geography, urban economics, land use planning, landscape design, and environmental studies have long recognized the land use impacts of transportation decisions, but these impacts are sometimes ignored in conventional transportation planning. For example, when planners consider widening an arterial or raising minimum parking standards, they generally focus on direct financial costs and give little consideration to factors such as the social and environmental impacts of increased pavement, or the possibility that it will leverage increased sprawl. Yet, these land use impacts can be comparable in magnitude to other costs and benefits that are normally considered in transportation decision making. The main concerns include land-take, habitat destruction and the loss of landscape quality.

Therefore, when new infrastructure is planned, it has to be assessed for the environmental as well as social and economic impacts it will create. These impacts are undertaken in cost benefit analysis and environmental impact assessments. There were found to be several types of Strategic Environmental Assessment groups in three study regions in relation to transport infrastructure (Fischer, 1999). The three regions are North West England (United Kingdom), Noord-Holland (Netherlands) and EVR Brandenburg-Berlin (Germany). The SEA types include:

- non–mandatory, policy-orientated transport SEAs/PPPs which may not include public participation, but does assess environmental as well as socio-economic effects,
- non-mandatory policy-orientated integrated spatial development visions with extensive public participation,
- mandatory policy-orientated or project landscape plans with public participation,
- Quasi-mandatory policy orientated transport assessments, without public participation and usually evaluated using cost-to-benefit and/or multi-criteria analysis.

Environmental and socio-economic impacts were assessed in 26 SEAs carried out within the three study regions. The environmental impacts assessed concentrated on the impacts on the flora and fauna, and the pollution and climate effects. The socio-economic impacts assessed

[22] Source: UNESCAP - http://www.unescap.org/tctd/rap/rap5.htm
[23] http://www.royalhaskoning.com/

concentrated on economic, demographic, housing, public service and social impacts. The results showed that environmental impacts were assessed to a greater extent than socio-economic impacts (Fischer, 1999). Environmental impacts were assessed in 23 of the SEAs, while only 16 socio-economic SEAs were carried out. Figure 1 shows the consideration of socio-economic impacts in the sample SEAs, and figure 2 shows the consideration of environmental impacts in the sample SEAs.

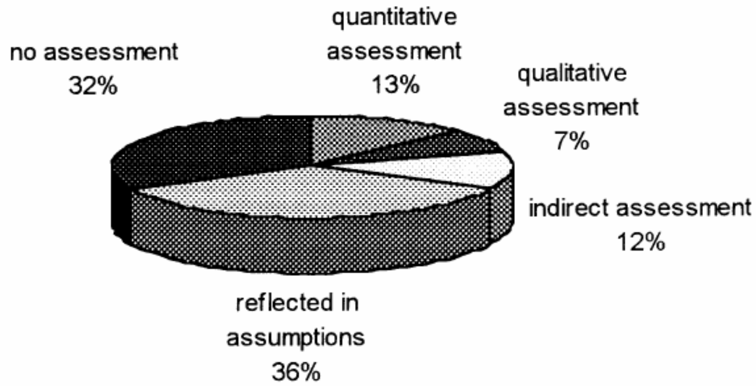


Figure 1: Considerations of socio-economic impacts in the sample of SEAs (Fischer, 1999)

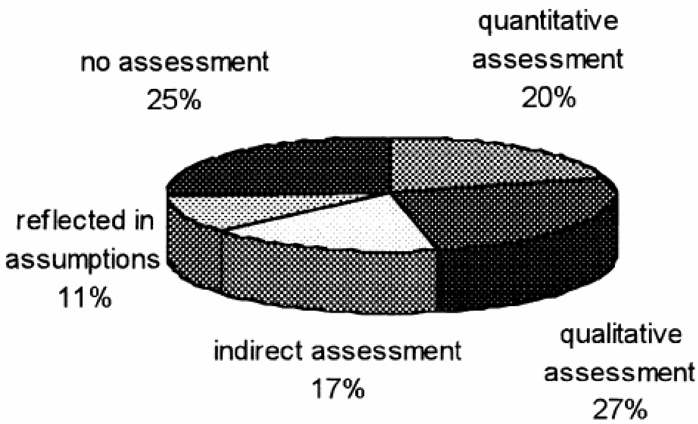


Figure 2: Considerations of environmental impacts in the sample of SEAs (Fischer, 1999)

The Environmental Impact Assessment procedure was introduced to overcome the limitations of classical cost benefit analysis that uses the criterion of the maximum total net benefit (benefit minus costs) to choose the optimum solution. The main limitations of such an approach are: first, that all the effects of a project are evaluated in monetary terms, so that when social and environmental aspects prevail, the method is completely inadequate; second, that the maximization of the total net benefit does not show the effects of a decision on the different objectives and the different social groups involved. Conflicts can therefore get ignored (Colorni, *et al*, 1999).

These limitations are particularly evident in the case of transport infrastructure. While both social cost and generalized travel cost need to be considered, these may include intangibles – such as social damage from air pollution or risk to life – that can be difficult to express in monetary terms, and a monetary criterion is not always acceptable from a social viewpoint (Colorni, *et al*, 1999).

<u>7.3.2.2 Implementation actors and processes</u>

There is little value in carrying out an environmental assessment process unless it is meaningful and it can have an input into the policy outcome; if at least some freedom of action exists. (Valve, 1999).

If there is some form of guidance on how to assess the impact of new infrastructure this makes it easier for the government and project partners to ensure their plans will be accepted. Legislative feasibility is helped a great deal in parts of Europe because the Commission alongside national policy makers generally recognise the fact that environmental and land use issues are tied up with transport and traffic. The LEDA project did however note that planning systems are often weak, in that they fail to integrate spatial development with transport and environmental aspects. The Netherlands and the UK were noted as examples of promising practise in this area.

Deliverable 1 of PROSPECTS found that no authority had exclusive responsibility for all relevant transport and land-use policy areas and that only 35% of cities managed their own transport and land-use responsibilities within one department. In addition, it was highlighted that city authorities often need to balance the interests of a number of different sectors, including other levels of government and a range of interest and stakeholder groups. It is likely to be difficult or impossible to implement a package of policy instruments where one influential group is particularly opposed to a particular element of that package.

In any event, public decisions regarding transport infrastructures, which produce a major environmental, social and territorial impact, can be facilitated by environmental impact assessment (EIA). In most countries this is explicitly required by legislation (Colorni, *et al*, 1999). Within the EU directive on SEAs only compulsory plans are subject to at SEA. PROSPECTS Final Workshop recommends that all large scale projects are includes in strategic plans would be a prerequisite to a really useful SEA.

A paradigmatic example is provided by the City of Vienna, that have recently finished a SEA of all existing strategic land use and transport planning proposals concerning the north-eastern part of Vienna. The subject of the assessment is a proposal to build a circular by-pass motorway around the city limits which would cross the national park of the Danube wetlands in a tunnel. In the SEA an attempt was made to combine a logical structure with intensive participation of stakeholders in a discussion with 40 stakeholders. At the end of the process a development strategy which differs from the original was devised. In particular a new site was found for the motorway-bypass, and all the delegates agreed (PROSPECTS, Final Workshop).

In Australia, they are trying to combat noise pollution associated with infrastructure use. In Western Australian the Government plan and design most regional roads with wide reservations and in conjunction with sympathetic land uses and building design.

A high proportion of industrial and commercial land adjoins these roads, in preference to residential development, and many are controlled access highways and any residential development is designed to face away from them (www.pc.gov.au).

In United Kingdom, the government has a series of Planning Policy Guidance's (PPG's) and Planning Policy Statements (PPS) that include the aim to tackle transport problems and land use planning. PPS10 sustainable transport includes the objective to secure proper integration between land use and transport policies a all levels – from national and regional down to local. PPS10 also tackles the issue of preserving the countryside from visual clutter, light and noise intrusion impacts against transport proposals.

The technical feasibility of assessing how the transport infrastructure will affect the urban area can be carried out fairly easily by environmental assessment companies with the co-operation of the people involved in the project. Carrying out an environmental impact assessment would not be the most expensive part of the infrastructure project, however if the results show that the environmental and social costs outweigh the benefits the new infrastructure will bring, that can have a large impact financially.

In any case it is increasingly clear that the public no longer welcomes the opening of new transport facilities with open arms. Now people seek quality of life instead of economic development, viewing environmental changes critically (Nakamura, H, 2000). Findings by the LEDA project back this up. They state that one of the most significant barriers is political and public acceptance and that the way to gain acceptance is through a consultation process and a targeted public awareness campaign.

Another relevant aspect for the implementation of new infrastructure is obviously securing adequate financing. One way to help finance transport infrastructure can be required from developers as part of the process of obtaining permission for development in the form of developer contributions. This approach has been applied successfully in the UK to secure finance for new roads and also for the provision of park and ride sites. More recent examples are for developers to contribute to public transport serving new developments in Edinburgh (PROSPECTS). In any event, the maintenance of the new infrastructure will ultimately lie with the government and local authorities or the transport companies that exist such as the Highways Agency in the UK. If the new infrastructure is for bus or rail services than part of the operational costs will fall to the user in fares. Parking charges or road pricing revenue may also be seen as ways of providing finance for new infrastructure.

7.3.2.3 Likely impacts

The 1999 UK SACTRA report found that under certain circumstances transport investment may have economic impacts additional to those measured in a conventional cost benefit analysis, but that they could be positive or negative (PROSPECTS, 2001). Since qualitative improvement of living is becoming more important in recent projects, economic evaluation based simply on conventional narrowly scoped cost-benefit analysis which only covers direct benefits in the transport market and project costs, is now insufficient for project evaluation.

New road construction was the traditional response to relieving congestion. However, new roads can give environmental improvements only if the roads they relieve are redesigned to ensure that people are discouraged from using them, in the same way they did with measures such as traffic calming. Moreover, if a new road is built it may give rise to inequities. New roads place the emphasis on the car, and are likely to encourage it's use for faster and longer journeys. This will in turn make public transport use, cycling and walking less desirable, and increase fuel consumption and carbon dioxide emissions. New roads if located away from urban areas in theory should also reduce accident rates by transferring traffic to purpose built roads, however this may not be the case if the new road encourages more new traffic (PROSPECTS, 2001).

Indeed, more research on the indirect network effects of new road construction would need to be done before this measure is taken up by a great many cities. In addition, the 1999 UK SACTRA report found that there is no clear unambiguous link between road provision and local regeneration. They recommend that close inspection be paid to road schemes which are developed for economic regeneration.

As concerns the relevance and measurability of effects and behavioural responses some topical elements concerning landscape compatibility can be found in the table below.

Table16: Relevance and measurability of effects and behavioural responses in the framework of landscape compatibility measures

Effects:	Likely relevance	Modelling capability
Capacity/congestion	Relevant - new infrastructure if deemed compatible can relieve congestion on some roads/rail lines but may cause more somewhere else	The introduction of a new road can be modelled to asses the affects on capacity and congestion
Direct user costs	Moderate relevance - costs can be high to pay for the use of the new infrastructure	
Reliability of journey	Low relevance – landscape compatibility will not be affected. If the new infrastructure is built then reliability may increase.	
Quality of journey	Relevant – new infrastructure should give a better quality of journey such as new smoother road surfaces.	
Information provision	Not relevant – new infrastructure alone will not increase information provision	
Environmental effects	Relevant – the infrastructure will only get the go ahead if the environment does not suffer great adverse affects, which the EIA should uncover	
Traffic accidents	Relevant – any new infrastructure given the go ahead especially roads will increase the chance of more accidents. If the number predicted is small then the benefits of the new infrastructure will mean it will get the go ahead.	
Health effects	Relevant - any new infrastructure near residential areas will increase the pollution levels causing adverse health effects. The land compatibility needs to be high for residents to approve the scheme	
Liveable streets and neighbourhoods	Relevant - new infrastructure near homes may make streets less liveable by increasing noise, pollution and possibly accidents. The benefits have to be great for the residents to allow the infrastructure to be built.	
Implications for government budgets	Moderate relevance – the government will have to fund part of the project even if it is not given the go ahead. Land compatibility needs to happen so future costs to the surrounding environment and people are kept to a minimum.	

Equity and social inclusion	Relevant – if the infrastructure is a new road then equity and social inclusion will be low for none-car households. Social inclusion may increase if the new road goes near rural locations. New PT infrastructure could also increase equity and social inclusion.	
Economic Growth	Moderate relevance – the new infrastructure can bring economic growth to areas by giving easier access to different locations for businesses.	
Change of location	Relevant - people may change location if the infrastructure holds greater social and economic benefits to where they currently are. They may also move location if the infrastructure goes ahead and adversely affects them	
Change of private vehicles ownership	Moderate relevant - new road infrastructure may cause an increase in private vehicle ownership, but new railway tracks and bus lanes may cause a mode switch, however landscape compatibility in the planning stage will not affect this.	
Change of PT season subscription	Low relevance - only if the infrastructure gave greater benefits to using PT instead of the car.	
Change of trip frequency	Low relevance – people will not change the frequency of trips for land compatibility. Would only change if new infrastructure allowed them to make one trip for the required activities, however that would depend on them all being in the same location.	
Change of travel destination	Low relevance - people will still need to visit certain sites to sustain daily life, landscape compatibility will not affect this.	
Change of travel mode	Moderate relevant - only if the new infrastructure gave greater benefits for switching, such as quicker journey times.	
Change of travel departure time	Moderate relevant - if the new infrastructure allowed a shorter journey time to work or other activities this will change departure times	
Change of route	Relevant – better infrastructure will make people change routes if the benefits are sufficient, i.e. quicker journey times and accessibility to activities.	
Change of driving pattern	Low relevance – people will still have to go to work and pursue social activities, new infrastructure may just change the route they take.	

The models that we will be using within Work Package 9 can cope with the introduction of new infrastructure to the current set of data, but it would be difficult to model giving priority to landscape compatibility in planning and building new infrastructure which is the nature of this specific measure.

7.3.2.4 Interactions with other measures

Measures which need to be implemented to facilitate others are required first. It will also be essential at least to be committed to those measures which generate income before investing in those measures which depend on that revenue for finance. Similar considerations arise with measures which influence public acceptability: commitments are needed to publicly attractive measures before embarking on those which on their own are less attractive. Here, however, there is the continuing risk that the less attractive measures will still not be implemented, for fear of public criticism. It is preferable if both positive and negative measures are implemented together (PROSPECTS).

Complementary measures tend to be in the form of land use planning to restrict the area that new infrastructure could be located, keeping new roads away from residential areas and environmentally sensitive areas. Land use planning can also influence what type of development can be built along this new infrastructure. Indeed, the development of high density mix locations may reduce the risk always associated with the building of a new road infrastructure, which without development control could lead to sprawl. If there is a mix of amenities and employment for the residents within the local area they will be less inclined to use the car to travel further a field.

Tied in with high density mix land use is the location planning of new infrastructure and industrial development. To try and minimise the conflicts between residents and industrial transport operators relocating new logistic and industrial activities away from highly populated areas may be the solution. This would mean locating them on the urban fringes but if the public transport system was also planned to ensure that residents could get to work at these location it would not increase the dependence on cars, but reduce the congestion at peak hours (Marshall & Lamrani 2003).

Traffic calming is also another complementary measure. If new roads need to be built one way to make it acceptable to local residents is to introduce traffic calming. This should make the road safer, and reduce the noise pollution.

To compensate for the cost of building new roads and the increased congestion that they may bring to an area, road pricing is increasingly becoming and option for governments. It can help recover some of the costs of building the infrastructure and contribute to it’s maintenance (PROSPECTS).

8. Parking measures

Most urban governments regulate parking markets, such as the downtown on-street parking market, workplace parking and the private-provision of off-street facility parking. Different types of instruments are commonplace. Take the on-street market, for example. Cities adopt differing combinations of meter fees, maximum length of stay restrictions, numbers of spots, as well as the enforcement and fines associated with either non-compliant or illegal parking.

Several questions follow naturally from these observations. What is the purpose of the regulation in general? Is it to alter parking behaviour per se, or also to alter travel behaviour more widely? Put differently, what would an ‘ideal’ allocation of parking space be like? Given a clear objective of the intervention, which policy instrument is most likely to deliver it? Might some instruments be preferred to others?

This chapter aims to review urban parking regulation. It stresses both the overall objectives of the regulation and the comparative efficiency of economic and non-economic instruments. Examples of economic instruments examined in this report include the meter fees, the subsidisation of workplace parking and fines for non-compliant parking. Examples of non-economic instruments include altering the supply of space; using time restrictions to regulate the on-street market and increasing the number of traffic wardens. In line with the general objectives of the SPECTRUM study, it should be noticed that regulation often requires combinations of economic and non-economic instruments. Efficient on-street regulation requires, for instance, the simultaneous setting of a meter fee and the number of traffic wardens. If, for whatever political or administrative reason, the probability of being caught parking illegally is small, the efficient meter fee is shown to be relatively low.

The structure followed in this chapter is somewhat different from the structure of the previous chapters. Since the welfare economic analysis of parking measures is relatively new, we have chosen to focus more on the economic reasoning behind different parking instruments. This allows us to identify the main components that should be evaluated in a cost-benefit analysis of these measures, the analysis of which provides a contribution to the subsequent urban case studies which will be carried out in SPECTRUM.

We do not present one all-encompassing model of urban parking. Rather, in order to keep the results clean, we proceed in small steps. Section 8.1 begins with the simplest useful model of on-street parking. It assumes a fixed supply of on-street parking space. Identical drivers park for a variable length of time. Perfect compliance is assumed. Such assumptions are not realistic, but such a setting allows us to highlight the key motivation for parking regulation per se, namely rationing demand to available supply. We then compare an economic with a non-economic instrument: a meter fee with a time restriction. The model is then extended to relax these ‘unrealistic’ assumptions. Firstly, we incorporate space in an explicit manner to gain insight into the efficient spatial distribution of parking fees. A final section considers how the presence of a (distorted) private facility market alters the efficient on-street meter fee.

The discussion thus far considers regulation of the on-street parking market per se. But decisions about parking are closely related to decisions about road use. In some cities (such as, for example Amsterdam), parking regulation is used as a means of reducing traffic congestion. Section 8.2 considers the efficiency of parking fees as a means of reducing congestion. It is shown that, in general, parking fees are not a perfectly efficient means of pricing congestion. However, the relevant comparison is between imperfect parking fee and necessarily imperfect road pricing schemes. Parking fees are shown to perform comparably with an imperfect single cordon scheme, and are cheaper to implement to boot.

Section 8.3 considers the efficient supply of parking space. In particular, we consider a common policy: reducing the supply of space as a means of making car trips unattractive, and thus reducing road congestion. The costs and benefits of this scheme are shown to depend on the price charged for parking and road use. This again reinforces the need for an integrated assessment of economic and non-economic instruments.

Section 8.4 relaxes another of the ‘unrealistic’ assumptions of the basic parking model: namely that of perfect compliance. Rather drivers decide whether to pay at the meter or not as the result of comparing the costs of non-compliance (being fined with some probability) with the benefits of non-compliance (not paying the fee). The notion of peak-load pricing is shown to be no longer useful. Rather, we develop the idea of the jointly-efficient level of meter fee and inspection probability. A final section considers the optimal delegation of powers between different layers of government.

The final section (8.5) considers a different parking market: the workplace. Several governments have sought to reduce the amount of free workplace parking as a means of reducing traffic congestion. This section discusses the optimal degree of subsidisation of workplace parking.

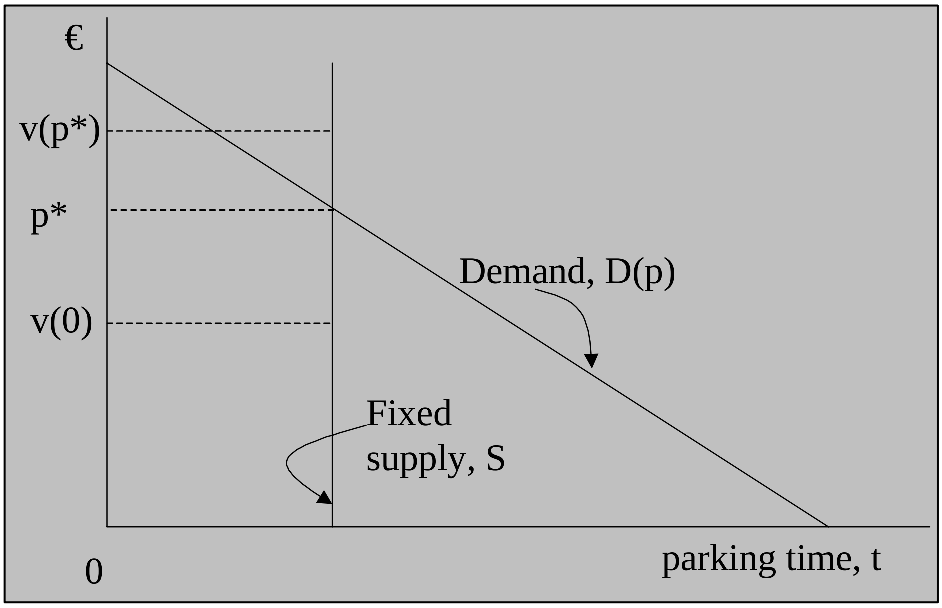
8.1 On-street parking

8.1.1 Peak-load pricing

The supply of city-centre on-street parking space is fixed, at least in the short-run. In the peak-period, demand typically exceeds supply. Some drivers are unable to park and must either wait, park outside the city centre and walk to their desired destination, or abandon their trip altogether. This is inefficient. Pricing on-street parking helps ration demand to meet available supply. It does so by influencing two margins of driver behaviour. Firstly, a fee per time unit encourages a shorter average length of stay and hence a larger rate of ‘turnover’ of spots. Secondly, it acts as a strong incentive to those drivers who place only a relatively low value on their trip to reschedule to the off-peak or switch to public transport.

Using prices to ration demand to supply is commonly known as *peak-load pricing*. We can illustrate this argument with a simple graph. Assume that a fixed number of spots are available such that the supply of peak-period parking time equals S. A fixed number of identical drivers must decide how long to park for, which, in general, depends upon the per-time unit charge for parking, p. Total demand for parking is denoted by D(p). A higher fee is assumed to reduce aggregate demand, and thus the demand curve slopes downwards.

Graph 1: Aggregate demand for parking function



Graph 1 depicts this case: it shows a downward-sloping aggregate demand for parking function[24], D(p) and the fixed supply of time, S. If parking is freely provided (p=0), demand is greater than supply i.e. D(0)>S. This is the relevant case for urban areas, at least during the busier times of the day.[25] The peak-load price, or simply the efficient price, is equal to p*. This is the price at which demand D(p) is rationed to supply, S. In other words, D(p*)=S. Why is this the efficient price? Consider pricing above this level, p>p*. If so, demand is less than supply. At least one driver can park longer at no extra cost to society. Reducing the price therefore increases total social benefit. Consider a fee below the peak-load level, p<p*. By definition, demand is greater than supply. 'Lucky' drivers, i.e. those who successfully find a vacant spot, park for a relatively long period of time, while the remaining 'unlucky' drivers are assumed to return home[26]. Consider raising the price. Each successful driver, as a result, parks for a slightly shorter period of time. In doing so, an extra driver is able to park. Total social benefit increases as long as the gain to a newly accommodated driver exceeds the losses to the remaining

[24] This is often referred to as an inverse-marginal benefit function. The marginal benefit function is a mapping from a quantity into a price. The demand curve is just the inverse of this function: i.e. a mapping from price into a quantity.

[25] If this were not the case, as e.g. is the case at night, or perhaps in rural regions, then prices do not have a 'rationing' role. While charging for parking may still be optimal for a tax-raising government, taxes are not required to ration demand to supply.

[26] Equally, they could park out of the city centre and endure longer walk times. In this case the marginal benefit needs to be interpreted as that net of the benefit of parking out of the centre.

parkers. This is the case as long as the demand curve is downward sloping, as seems reasonable.

The idea of applying peak-load prices to on-street parking space was first discussed in the seminal paper in this area by the Nobel-prize winning economist, William Vickrey (1959). He points out an immediate difficulty in implementing such an idea. To set the optimal price, the administration needs to know the demand curve, D(p). Although sophisticated techniques exist for measuring demand, most urban transport authorities make decisions on pricing without the aid of formal analysis. In effect, demand is uncertain. Vickrey suggests to set '*demand-responsive meter fees*'. The price at each meter in a particular district varies according to a simple algorithm. The higher the occupancy rate of spaces in a particular vicinity, the higher the fee. If all spaces are vacant, for instance, parking might be free. As spaces fill up, the fee rises. If only one or two spaces remain, the price might spike quite sharply. In simple terms, the price adapts to demand conditions such that one spot remains vacant most of the time.[27]

Charging the peak-load price is closely related to the idea of charging for the *marginal external search cost* of parking, which is the other major normative result of this literature (see Arnott and Rowse, 1999, or Anderson and De Palma, 2003). In this formulation, drivers search for a vacant space. The average search time is assumed to increase as demand relative to supply increases. A driver's decision to park for an extra unit of time, and thus increase demand, imposes marginally higher average search times on all drivers. This is a classic example of an *externality*. The efficient parking fee equals the marginal external search cost, i.e. the additional search costs incurred by all other drivers as a result of an individual's decision to park for an extra unit of time. Viewed this way, the efficient charge for on-street parking can be seen as closely related to an efficient road-price, i.e. the charge for use road space.

Result 1: *The efficient price for on-street parking space is such that demand is rationed to supply (the peak-load price). Equivalently, the efficient price is such that each parker is confronted with the full marginal external cost parking.*

8.1.2 Time restrictions

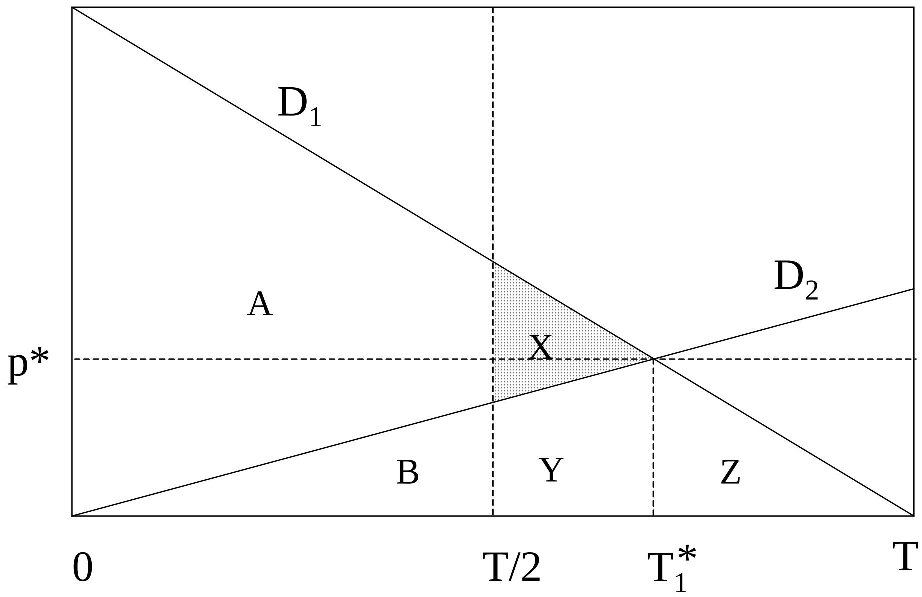
The discussion so far has focused on efficient pricing. Yet on-street parking is often regulated via time restrictions rather than prices (or a combination of both). Time restrictions, however, do not result, at least in general, in an efficient allocation of parking demand to supply. This is shown in Graph 2. Imagine two *non-identical* parkers competing to use a spot for T units of time.

[27] Although appealing, this idea generates an efficient parking market only if drivers know the time profile of fees. Otherwise a driver may leave his car parked at a relatively cheap rate, only to return to discover that the fee is much higher than he'd anticipated.

The demand curve for the first driver is given by D_1, where, as before, we assume that the marginal benefit declines with additional time parked. If person 1 parks for T_1 units of time, person 2 parks for the remaining $T-T_1$ units of time.

Her benefit as a function of T_1 is given by D_2, which is just her demand curve read from right to left.

Graph 2: Efficient allocation of parking demand to supply



A simple time restriction would allocate $T/2$ units of time to each individual. If so, individual 1 receives a total benefit of area A+B. Individual 2 receives a total benefit of area Y+Z. Total social benefit, therefore, is A+B+Y+Z. But this is not efficient. Rather, the combined benefit is increased when person 1 parks for T_1^* units of time. In this case, the total benefit to individuals 1 and 2 become, respectively, A+B+X+Y and Z. Total social benefit is, therefore, A+B+X+Y+Z. This is achieved by adopting a fee equal to p*. Person 1 duly parks for as long as his marginal benefit is greater than the price, i.e. for T_1^* units. Shaded area X gives the loss in welfare from adopting a non-economic instrument.[28]

[28] This result clearly depends on drivers being non-identical. If both drivers have the same demand curve, the time restriction T/2 is optimal i.e. X is zero. This can also be seen in Graph 1, where demand can be rationed to supply if, with N drivers, each parks for S/N units of time. However, given the heterogeneity of uses in urban parking space (shoppers, workers, loading/unloading), assuming identical drivers seems highly implausible.

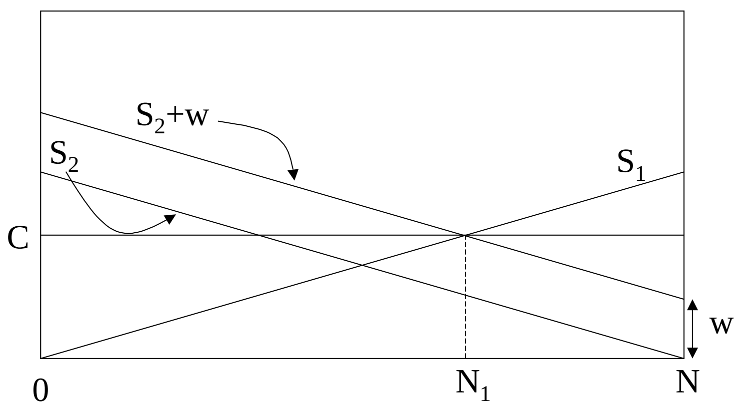
Result 2: *With non-identical drivers, non-economic instruments, such as time-restrictions, are less efficient than price instruments.*

8.1.3 Spatial pattern of prices

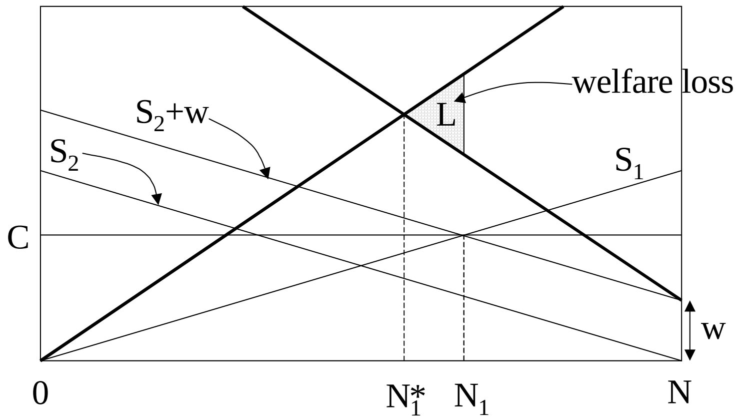
The discussion so far has not explicitly considered space. But any transport authority must set prices across different parts of the city. What might the distribution of efficient fees look like? Anderson and De Palma (2003) consider an explicitly spatial setting for on-street parking. A single point CBD is surrounded by a series of ever more distant concentric streets (with associated on-street parking). Each driver makes a trip to the central business district, but can park either relatively close to the centre (with small walk costs), or park relatively far from the centre (with larger walk costs). In equilibrium drivers must be indifferent between parking in any one ring. Thus drivers spread out such that the average search cost for finding a vacant spot plus the walk cost from any one ring are equal across all rings. This implies that the number of parkers falls with distance from the city centre.

We can illustrate the central message of their model with a particularly simple 2-ring example. Ring 1 is the CBD itself and thus entails a zero walk cost. Ring 2 entails a walk cost, w. A fixed number of drivers, N , are assumed to park. The average search time to find a vacant spot in either ring is assumed to be an increasing function of the number of drivers deciding to park there. Graph 3A shows the set-up. S_1 depicts the average search time in ring 1 as a function of the number of parkers. Drivers not parking in ring 1, $N-N_1$, are assumed to park in ring 2. S_2 gives the average search cost on ring 2 as a function of the number of parkers in *ring 1*, N_1. Parking on ring 2 entails a cost per driver of S_2+w. In equilibrium, drivers split between the two parking markets such that the average cost is equal. This occurs when N_1 drivers park on ring 1, and the remainder on ring 2. The combined search and walk cost is equal to $0C$ on either ring.

Graph 3A: Average search time to find a vacant spot



Graph 3B: Minimisation of total parking costs



The spatial distribution of parkers is not efficient. Total parking costs are minimised when the marginal cost of parking on each ring is equal. As shown on Graph 3B, this occurs when $N_1^* < N_1$ drivers park on ring 1. Free parking encourages too many people to search too close to the centre. The efficient parking gradient is flatter (i.e. more people park further away from the centre) than that associated with free parking. The welfare cost of the inefficient spatial distribution of parkers is shown by area L.

Result 3: *Free on-street parking results in too steep a gradient of parking. The efficient parking fee function declines with distance from the city centre, and flattens parking gradient.*

8.2 Off-street parking

The discussion thus far has focused on the on-street parking market exclusively. But in many urban areas the on-street market is competing with a privately-operated off-street parking market (henceforth *facility* parking). In many cities, facility parking is more expensive than on-street parking. As a result, drivers have a strong incentive to invest time into 'cruising' the central area for a vacant on-street spot. Calthrop and Proost (2003) explore this idea in a formal economic model. They show that if the facility is priced competitively and supplied under constant-returns-to-scale, efficient on-street parking policy is to *match* the price charged at the facility. This is a particularly simple rule to implement – in particular, the local transport authority needs no information on parking demand or marginal external search cost.

In practice, however, facility parking is unlikely to be very competitive. If so, the efficient on-street price is more complicated to establish. Calthrop and Proost (2003) consider the special case in which a single supplier of facility parking competes with the (government provided) on-street market. The government is assumed to set the price of on-street parking first. After observing this, the supplier of facility parking sets his price. Crucially, therefore, the government knows that its choice of price will affect the price charged by the monopolist. The monopolist faces a choice. For any given price on street, it can either (i) undercut that price and capture the whole market, or (ii) charge a profit-maximising price, i.e. above the on-street price, in the knowledge that only those drivers who are unsuccessful in finding a vacant on-street spot will use the facility. The facility gains only the ‘residual demand’ for parking.

Consider the incentives facing the monopolist if the price charged on-street is relatively low. Undercutting this low price is not attractive. The monopolist prefers to charge the profit-maximising price and receive only residual demand. Pursuing this strategy is more profitable because the increase in profit per unit of parking demand more than outweighs the loss from receiving fewer units of demand. Now consider the alternate case: if the price on-street is relatively high. Undercutting is now more profitable than charging the profit-maximising price. The increased demand from undercutting boosts profits by more than the loss from setting a lower price per unit.

Calthrop and Proost (2003) investigate a numerical model of the central London parking market. Drivers decide how long to park for and whether to search for an on-street spot or use a private facility. A surprising result emerges. Under plausible parameter values, the efficient price for on-street parking is the lowest price that induces the facility to undercut the on-street market. The on-street parking market remains unused in equilibrium. This is counter-intuitive, until one realises that the on-street market has a strategic value as a means of lowering the (excessive) price charged at the private facility. While this model is too simplistic to be translated directly into policy, it does remind us that the on-street market can be used to influence the behaviour of facility parking.

Result 4: *In the presence of a competitive facility parking market, the efficient pricing rule for on-street parking is simply to match the facility price. This ‘rule-of-thumb’ has the advantage that government needs only a minimal amount of information. If the facility market is not competitive, the price of on-street parking can be used to alter the equilibrium price of facility parking. Under some conditions, the efficient on-street price turns out to be the lowest price at which the facility is induced to undercut the on-street market.*

8.3 Using parking to tackle congestion

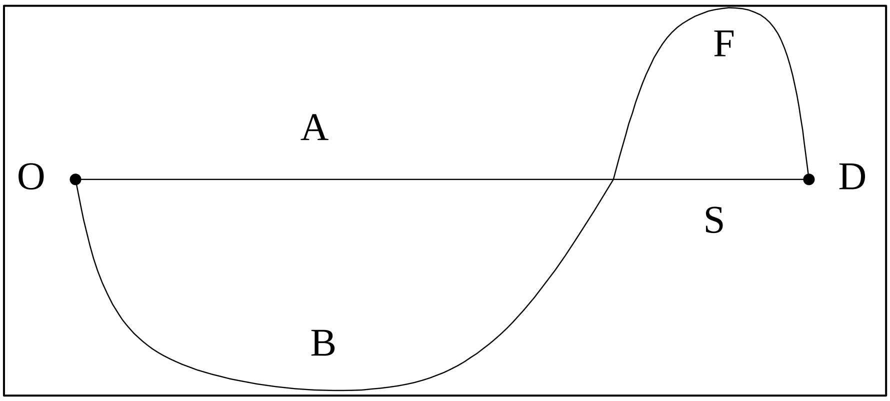
Economists have long studied the problem of traffic congestion. The common consensus amongst academic economists is that a set of road tolls is required to improve the efficiency of the urban transport market. By contrast, many practitioners have advocated raising city centre parking prices to discourage traffic and hence congestion.[29] This section discusses the efficiency of using parking fees to *second-best price* road congestion. To focus matters, we abstract from all of the issues discussed in the previous section with respect to on-street parking, such as search costs etc.

[29] This has also been put into practice: a notable example being Amsterdam in the late 1990s. The price of on-street parking doubled in a short space of time. The main reason used to justify this policy was to reduce congestion.

As is well documented in the literature, road space is efficiently priced if each driver is confronted with the full *marginal social cost* of his or her trip.[30] We focus in this section on congestion alone.[31] Road space is efficiently priced, therefore, if road tolls are set at marginal external congestion cost.[32] Congestion costs, however, vary according to the time of travel and the route chosen. It follows that a perfectly efficient system of road tolls varies across links on the traffic network and continuously over time. Such a scheme – if technically possible to implement at all – is prohibitively expensive. The fully efficient use of road space is therefore little more than an interesting benchmark against which to compare actual (and much blunter) policy, such as the area-wide congestion charging scheme in London or, for our purposes, higher parking fees.

Again we can use a particularly simple model to illustrate ideas. Imagine two links, A and B, joining a city suburb (O) with the centre (D). Furthermore, assume that link A is a main road (i.e. with a large capacity) and link B is a minor road (with a small capacity). In the centre, drivers can park either on street (market S) or at a private facility (market F). We assume all trips take place in the peak period. Graph 4 shows this 'virtual' network. In this highly simplified setting, the perfectly efficient system of road congestion tolls requires a separate congestion toll on links A and B only. If this is available to government, there is no rationale for using the price of on-street parking (link S) to tackle congestion. Interest in parking fees as a means of reducing congestion, therefore, is only relevant to a world without a full set of road tolls.

Graph 4: Perfectly efficient system of road congestion tolls



Consider a special case of our model: no road tolls exist, and all parking is on street (i.e. via link S). In this case, raising the price of parking acts as a uniform toll on both links

[30] See Small (1992) for a thorough discussion of the rationale behind road pricing.
[31] Road transport is typically associated with a range of externalities: congestion, air pollution, climate change, accidents, noise, road damage etc. We focus only on congestion to simplify matters, but hopefully the reader can see that the addition of other considerations does not change the structure of our argument. It is perhaps also relevant to note that empirically, at least in Europe, congestion is by far the largest component of total marginal external cost (see De Borger and Proost, 2002).
[32] This statement needs some qualification. Recent literature shows that pricing at marginal external cost is only the efficient rule if government has access to non-distortionary taxes (Bovenberg and van der Ploeg, 1996). This is typically not the case. We choose to abstract from this issue in this section, although it has direct bearing on the discussion of workplace parking fees in section 6 below.

A and B. As shown in Calthrop (2003), under these conditions, the optimal parking price equals:

$$p = \alpha MEC_A + (1-\alpha) MEC_B$$

where the parameter α depends on, amongst other things, the ratio of the own-price elasticity[33] of link A (with respect to the price of parking) to link B. The optimal parking price is just a weighted-average of the two marginal external costs, where the weights depend on the relative elasticities. Clearly, if the marginal external congestion costs is identical over the two routes, the parking fee can ‘mimic’ the perfectly efficient set of road tolls. However, in general, this is not the case. Why do the weights depend on relative elasticities? This is intuitive. On any one link, deviating from marginal congestion cost is more costly to society the larger the change in demand. Hence in our setting, if say link A is relatively elastic, it receives a higher weighting in our average, and the final price is closer to MEC_A.

Consider another special case. All drivers use link A, which is not tolled, but drivers choose between facility and on-street parking. The government can alter the price of on-street parking, but not that of the privately-operated facility. Under these circumstances, the optimal on-street price equals

$$p = MEC_A(1-\beta)$$

where variable β depends upon the ratio of the cross price elasticity of facility parking (with respect to the price of on-street parking) and the own-price elasticity of on-street parking (see Glazer and Niskanen, 1992, for a similar result). The greater the absolute value of the cross-price elasticity, the lower the optimal on-street fee. The intuition is straightforward. In an extreme case, if all demand switches from on-street to facility parking (i.e. $\beta \to 1$), there is no effect on congestion at all. Raising the fee only distorts choice, without reducing congestion. It is therefore not efficient to set a strictly positive fee at all.

Our previous examples are simple, but capture the essence of why parking fees are less efficient in tackling congestion than an ideal set of road tolls. In particular, parking fees cannot be made to depend upon the route chosen. Hence the parking fee can at best be set as a weighted average of the link-specific marginal external congestion costs on the network. Secondly, it is difficult for government to raise all parking prices simultaneously. Realistically, at least in the short term, it can only raise the price of parking on street, which may just induce drivers to switch to private parking markets. Again, the net impact on congestion levels may be only relatively minor.

It is important not to dismiss parking fees too quickly, however. Although parking fees are only an imperfect means of tackling road congestion, so too are practical road pricing schemes. The relevant question is therefore how much less efficient parking fees are than, for instance, an area-wide congestion charge or a single or double cordon-scheme. As a rule of thumb, more sophisticated charging schemes produce higher

[33] An elasticity is a unit-less measure of the responsiveness of demand to a price change. It is usually expressed as a positive number.

benefits but only at greater implementation costs. While a uniform parking fee is probably less efficient than a double-cordon congestion scheme, it is also probably a great deal cheaper to implement and administer. A full cost-benefit analysis might well favour 'blunt but cheap' policies, such as higher parking fees, rather than expensive (and perhaps only slightly less blunt) road pricing.

A flavour of this result is captured in Calthrop *et al*., 2000, using a numerical simulation model of Brussels (TRENEN). The model contains over 30 transport markets. It is used to compare the welfare gains from higher city centre parking fees with a single cordon charge and lower public transport fares. By assumption, the parking fee is paid by all drivers, whereas only commuters cross the cordon. The parking fee is assumed constant over time i.e. not differentiated between the peak and off-peak.[34] The results suggest that both policies have broadly similar overall impacts on welfare. Both attain approximately 50 per cent of the welfare gain available from a 'perfect' pricing scheme. Importantly, the analysis does not consider implementation costs. Doing so would presumably lead the policy-maker to favour parking fees over a single cordon charging scheme.

Result 5: *Parking fees are an inherently second-best means of reducing road congestion. There are two reasons for this. Firstly, parking fees cannot be made to depend upon route chosen. Secondly, at least in the short run, only the price of on-street parking can be raised. Drivers can easily 'avoid' the fee by switching to facility parking. The final impact on congestion is, therefore, rather small. However, practical road pricing schemes are also inherently second-best. While parking policies may or may not produce lower benefits than a realistic road pricing scheme, it almost certainly enjoys lower administrative and implementation costs.*

8.4 Controlling parking supply

As well as regulating the price of on-street space, government controls the supply of on-street space.[35] One common policy is to reduce the number of on-street spots. This is justified on the grounds that, by making trips less attractive, demand, and thus congestion, will fall.

Consider decreasing the number of on-street spots along, for example, a particular stretch of road in the city. As a direct result, the average search time (for a vacant spot) increases. Against this, however, the measure may benefit drivers in two ways. Firstly, 'cruisers' are thought to hinder traffic. Removing space may increase average travel speed along the relevant stretch of road. Secondly, the abandoned space may be used to extend road capacity, which in turn reduces journey time. A simple cost-benefit test of

[34] The model does not contain route choice and hence probably biases the results in favour of parking fees. This is partially compensated for, however, by assuming that parking fees cannot be differentiated between the peak and off-peak.
[35] It is clear that, via planning consents, the government also controls the supply of private facility parking. We do not consider this policy here.

reducing on-street supply would quantify these various effects, and proceed only if the benefits outweigh the costs.

Calthrop (2003) considers the optimal supply of parking space in a formal economic model. The analysis incorporates the direct costs and benefits of altering capacity already mentioned. In addition, however, the model incorporates pricing distortions on each transport market. This adds additional costs and benefits at the margin from altering supply. Reducing supply, for instance, gives rise to additional benefit if reduces the number of car trips and if those trips are under-priced.
The results show how the cost-benefit test for altering capacity depends on the price charged for on-street parking. If on-street parking is under-priced and demand is therefore relatively high, the increase in average search time may be rather high. Against this, precisely because the parking market is also distorted, reducing on-street parking activity may be beneficial. In short, while the analytical model is useful in identifying the components entering a cost-benefit test, a numerical model is needed to quantify effects. As Calthrop (2003) argues, the empirical evidence on search behaviour is extremely small. There is clearly a need for greater survey work to help quantify important elements in our cost-benefit test.

Result 6: *In considering the costs and the benefits from altering the supply of on-street space, it is important to account for pricing policy. For instance, removing on-street parking space is sometimes advocated as a means of tackling congestion. While such a policy may reduce congestion, it is also likely to increase average search time for on-street space. If on-street space is priced inefficiently, this latter cost may outweigh any benefit from lower congestion.*

8.4 Enforcing on-street parking policy

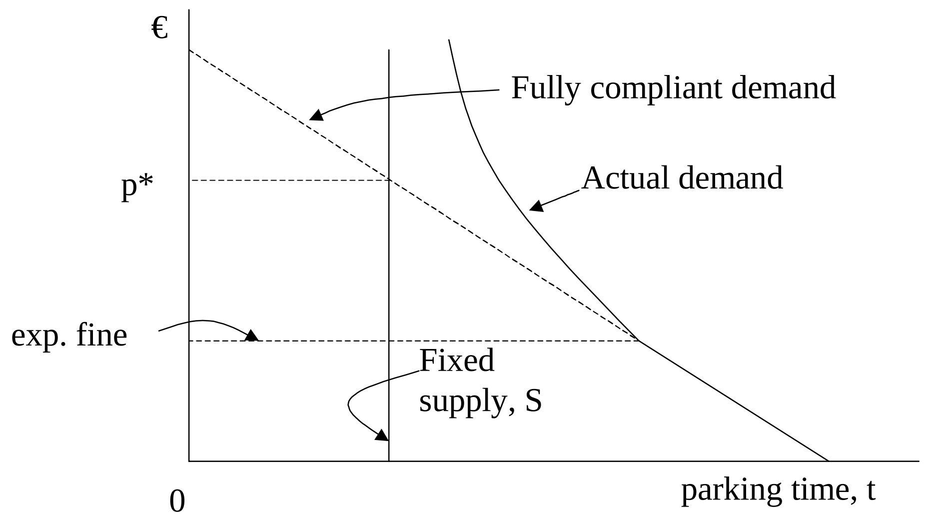
We have (implicitly) assumed thus far that drivers fully comply with any parking fee or time restriction introduced by the government. This is clearly not the case in practice. Yet enforcing payment is costly to the government. It will be shown that this complicates the message for efficient pricing.

Consider a driver facing a choice between paying a meter fee or not. If he does not pay, he risks a fine with a certain probability. For instance, if the fine is €50 with probability of 0.1, we may speak of an expected fine of €5. Interestingly, however, economists working on compliance issues have repeatedly noted that, even when the expected fine is considerably less than the fee, the majority of people pay the fee.

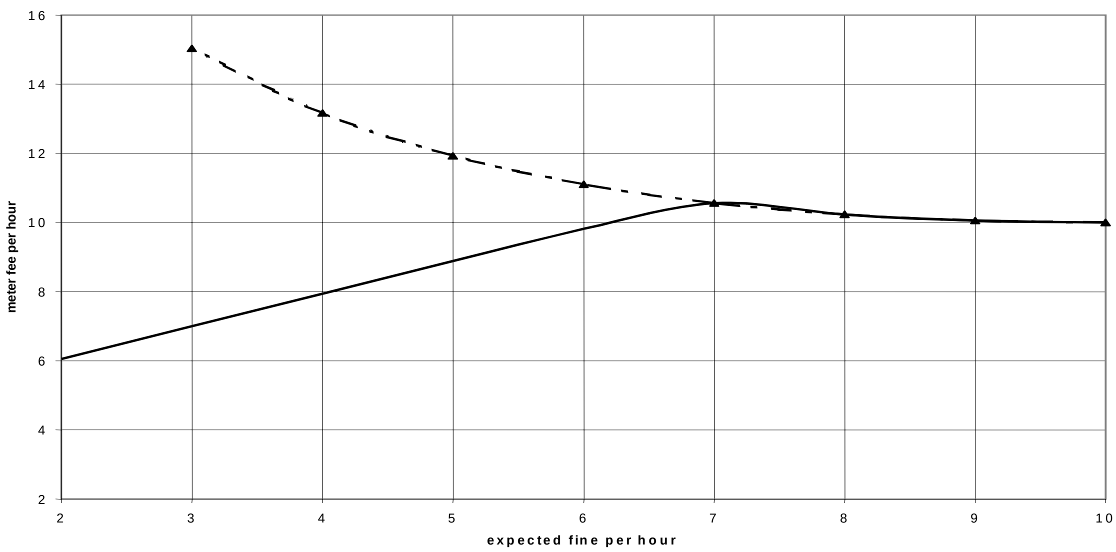
This suggests that there is an additional 'physic' cost from committing an offence, which may vary considerably from person to person. Hence, while some people may not pay once the meter fee is only slightly above the expected fine, others may continue to pay even when the fee is several times higher than the expected fine.

The efficient price of on-street parking is complicated by the presence of imperfect compliance. Earlier, we defined the notion of a peak-load price – the price at which demand is rationed to supply. But with non-compliant behaviour, it may not be possible to ration demand to supply. Raising the fee may be met by increasing non-compliant behaviour. And, put loosely, if most drivers do not pay, there is little point in raising the fee in an attempt to reduce demand.

Graph 5: 'Fully-compliant' demand curve



Graph 5 demonstrates this point. The 'fully-compliant' demand curve shown is simply the demand curve from Figure 1. Demand is rationed to supply at the price p*. Once drivers are able to choose not to pay the fee, however, *actual* demand differs from 'fully-compliant'. At any fee above the expected fine, some drivers choose not to pay and hence do not alter behaviour in response to the fee. Actual demand exceeds the fully compliant case (at least at all prices above the expected fine). Moreover, there exists no price at which demand is rationed to supply.



Graph 6: Optimal parking fee in a efficient on-street parking pricing with non-compliant drivers

Calthrop (2001) builds a formal economic model to investigate efficient on-street parking pricing with non-compliant drivers. A numerical model is calibrated to central London (using information largely provided by Brown, 1991). Graph 6 presents the optimal parking fee from this model, as a function of the expected fine level. The broken-line gives the peak-load price with full compliance. The continuous line gives the efficient fee (the units are 1995 £'s per hour). Notice that for a relatively low level of expected fine, the efficient price is below that required to ration demand to supply. A relatively high fee simply induces most drivers to park in a non-compliant manner, and hence produces little reduction in aggregate demand. Only once the expected fine is relatively high – approximately £7 per hour - is it efficient to ration demand to supply.

In the discussion thus far we have taken the level of the expected fine as given. But, returning to Figure 6, if the expected fine can be raised to a level above p*, demand can be rationed to supply at the peak-load level p*. Moreover, at the efficient fee, all drivers comply. Recall, however, that the expected fine comprises two elements: the fine multiplied by the expected probability of being caught offending. The size of the fine is, at least in many settings, fixed to the transport authority.[36] Hence in order to raise the level of the expected fine, the government must raise the inspection probability. But this is typically costly (more traffic wardens, perhaps equipped with more expensive technology etc). This implies a straightforward trade-off for government. The more costly it is to raise the inspection probability, the lower the expected fine, and, following from Figure 7, the lower the efficient meter fee. Put loosely, if enforcement is relatively costly, it is worthwhile paying the price of a poorly rationed parking market in order to save on enforcement costs.

Result 7: *If drivers are (potentially) non-compliant, the efficient fee to park on-street depends on the expected fine from non-compliant parking, which in turns depends upon the costs of inspection. A relatively poorly rationed parking market may be a rational response to relatively high costs of enforcing payment.*

In practice, the local transport authority may not receive the revenue from fines (for non-compliant parking acts). As discussed in detail in Calthrop (2001), this particular institutional feature may induce a local transport authority to set either excessively high or low inspection probabilities in an attempt to stem the flow of fine revenues out of the local community. Which outcome occurs is shown to depend largely on the cost of raising the inspection probability. If it is relatively costly, the transport authority may be tempted to set extremely low inspection levels: not catching offenders is an effective means of preventing fine revenue flowing out of the local community. Conversely, if enforcement is relatively cheap, excessively high inspection probabilities may be set. A high expected fine induces most drivers to pay at the meter, and thus again thwart the transfer of fine revenues out of the community. Calthrop (2001) uses such a model to explain the persistence of low meter fees and inspection probabilities in central London during the 1970s and early 1980s.

[36] Even if the level of the fine is variable, it is not obvious that the fine should or can be increased. If people are averse to taking risks, it may be highly unpopular to introduce high fines for overstaying on a parking meter. Likewise, if there is some probability of falsely charging compliant drivers – e.g. the parking meter technology is not perfectly accurate, it is questionable how desirable high fines are.

Result 8: *A transport authority faces perverse incentives in determining the level of the meter fee and inspection probability if it does not receive the revenue from non-compliant parking acts.*

8.5 Workplace parking

Despite significant resource costs[37], many employers choose to provide free workplace parking. Shoup (1997), for instance, reports that 95 percent of Americans park for free at the workplace. Free workplace parking encourages commuters to drive rather than use public transport. If, for political or cost reasons, congestion tolls are not available, government might consider regulating to increase the price of workplace parking.

Shoup (1997) examines recent legislation in California, instigated in response to concerns about air pollution, under which employer paid parking is transformed from a matching grant for driving into a block grant for commuting[38]. The primary effect of the scheme appears to be a shift to car-pooling. In the U.K., London Boroughs are entitled to impose a workplace parking tax, specifically in the belief that 'free parking at the workplace accounts for a significant of peak-hour congestion'.

The case for removing the subsidy to workplace parking may seem compelling. But two arguments cast doubt. Firstly, as seen in section 3 above, parking fees are, in general, poorly targeted towards congestion. Congestion is a link and time specific phenomenon, whereas parking fees tend to be independent of route chosen and largely independent of time travelled. Secondly, higher parking fees act partially as a tax on labour supply. Given that labour taxes cause relatively high distortion-like costs at the margin in most industrialised economies, there is a rationale for setting low taxes (even subsidizing) complements to labour supply (see Calthrop, 2001, or Corlett and Hague, 1957).

Calthrop (2001) uses an applied general equilibrium model to assess the 'optimal' level of workplace parking fee, which balances these various factors. Consumers travel for two different purposes: to commute to work, and for leisure purposes. Three modes exist: a motorway, which is congested and a minor road and rail mode, both of which are assumed non-congested. Workplace parking fees are poorly-linked to external costs in two dimensions of the model: firstly, the fee affects back-road commuters (who are assumed not to generate congestion), and, secondly, the fee does not affect the behaviour of motorway leisure drivers.
The numerical results show that the optimal tax on workplace parking is approximately zero. Higher taxes cannot be justified on congestion grounds, as the instrument is only a relatively inefficient way of tackling the problem. Likewise, the argument for

[37] For instance, Shoup and Wilson (1992) report that the resource cost of parking in Los Angeles is $4.32 per day, while Banister (1990) estimates the costs of off-street parking in London at £5.15 per hour.
[38] Under the legislation, employers must offer all employees the option of choosing a cash refund in lieu of any parking subsidy. The code only applies to employers of 50 or more people in regions that do not meet the State's clean air standards. Furthermore, cashing out is only applicable to those parking spots that an employer rents from a third party.

subsidizing the complement to labour supply is not empirically strong enough to justify a subsidy.

Result 9: *Taxing 'free' workplace parking has some scope in reducing congestion. However high taxes on workplace parking are difficult to justify*.

8.6 Concluding remarks

The central message from each section is summarised in situ, and there is little point in repeating that information again. Rather, we conclude by considering the limitations to the analysis thus far.

Firstly, the modelling of driver search behaviour is too simplistic. In practice, drivers face a complex task: deciding where to begin searching, how to search across a grid network, how often to repeat a particular search, when to switch to a facility or give up. Effective policy to reduce search costs probably needs to account for these margins of behaviour.

Secondly, there is an almost entire dearth of information on actual search behaviour. For instance, how long is the average search time in a particular city? As important, how does this vary as a function of the occupancy rate of spots? Such information is crucial in determining the actual level of the efficient fee. Good applied empirical work is also missing on the effects of actual policy. Different cities have applied different types of regulation over time. In principle, there is sufficient variation in the datasets to extract useful elasticity measures.

Thirdly, in practice parking regulation is concerned with 'long-term' and 'short-term' parking. It seems to be considered desirable to separate these types of parking markets. This is done by a combination of parking fee and time restrictions. Our basic model does not provide much insight into whether this is desirable or not.

Finally, we have focused almost exclusively on the downtown street market. But government regulates off-street non-residential supply via the planning system. For instance, the tradition concern in the UK was that private retailers would undersupply parking space, and hence there was a minimum number of spots per square metre of space. More recently, however, with growing concern over the impact of out-of-town retail centres on local congestion, the regulation switched to a maximum number of spots per square metre.

9. Public transport instruments

Public transport is in general considered as an environmental friendly alternative for car transport. Policy measures that increase the share of public transport in total passenger transport and decrease the share of car transport are therefore to result in lower CO_2 emissions. The attractiveness of public transport services can be increased by improving service quality and by a stimulating pricing policy.

As to improving public transport quality a wide range of measures that increase frequency, speed and the punctuality of the services exist. Infrastructure investments in cities as the delineation of dedicated bus or tram lanes, or priority rules favouring public transport could contribute to these goals. Several sources indicate that potential increases of bus and trams speeds of 10% up to 20% and even higher increases in reliability are possible in European cities[39]. However, as already pointed out while discussing bus lanes in Chapter 4 (see Section 4.1), this kind of infrastructure policies will have important side effects as a drop in average speed of cars and trucks as fewer driving lanes are left for private transport. As a consequence, congestion costs for users of these modes will increase. These side effects can lead to significant welfare costs as an important share of car drivers and almost all freight transport in cities can not switch to public transport.

For instance, the Auto-Oil II Part IV Annex 4 reports that average bus speed of in Athens could be increased by 15% by delineating dedicated bus lanes and giving buses unconditional priority at intersections. In 2005 the improved infrastructure could lead to an increase in bus transport by 5,1%. Car transport (-1,1%) and truck transport (-0,1%) would decrease. The measure would result in a rather limited reduction in CO_2 emissions of road transport in Athens (-0,3%) and a welfare cost of € 3,28 per capita in 2005. The decrease in pollution and accidents as well as the time savings for buses do not compensate the increase in congestion costs for cars and trucks and the infrastructure costs. Moreover the welfare cost of the measure increases over the years (e.g. € 9,63 per capita in 2010) as a positive trend in car and truck transport is forecasted and consequently the effect of increasing congestion costs gains importance.

Next to improving public transport quality, pricing policies could make public transport more attractive. Such measures would reduce environmental issues and congestion costs, but require increased public transport subsidies. We may quote again the simulations in Auto Oil II, Part IV, Annex 4 for Athens, which analyse a decrease of bus- and metro tariffs by 30% in 2005, resulting in a decrease of car transport by 3% and an increase in public transport usage by 15,3% for bus and 13,2% for metro. Total passenger-kilometres would increase 2,1% and transport CO_2 emissions would drop by 1,2%. The reduction in fares and lowered congestion costs for passenger and freight transport would lead to an advantage for consumers sufficiently large to compensate the increase in public transport subsidies.

[39] London Transport Buses, the London Bus Priority Network, 1997; and DITS, TTR, Public transport prioritization, Transport Research APAS, Urban Transport, vol. 25, Luxembourg 1996

However, the European transport sector currently shows a cost advantage in favour of private transport relative to public transport modes as car drivers do not pay for the external cost of congestion, air pollution, noise and accidents they cause. From an economic point of view tax increases on car transport would better reflect resource and external costs of private transport. In this situation, lowering public transport fares may correct the *relative* cost advantage for cars, but will lead to public transport prices that are significantly below its real cost and thus further *subsidies* are needed. Note that such subsidies can attract present public transport users and such population groups that, at the moment, rarely use any motorised mode to use public transport unnecessarily, giving rise to demand for more public transport capacity and thus causing additional costs.

Some important public transport instruments have been already discussed in the previous chapters of this deliverables, namely *bus lanes* within section 4.1 dealing with reallocation of road space by introduction of dedicated lanes and *PT management, information and control systems* within chapter 6 dealing with Intelligent Transport Systems. In the following we will summarise some of the remaining public transport instruments, illustrating briefly their general characteristics, implementation actors, likely impacts and interactions with other measures.

9.1 Bus prioritisation

9.1.1 General characteristics

Bus priorities are a group of measures for buses to bypass congested traffic and hence to experience reduced and more reliable journey times. The most common measures are selective detection at signals or automatic bus location to give priority at signals throughout the network and UTC timings weighted to favour buses. Others include bus-gates or bus only sections (maybe restricted by time), bus by-passes, exemption from banned turns, placing bus stops in a strategic way to block car traffic etc. Bus access to pedestrian areas are designed specifically to reduce the adverse impact on buses of certain traffic management measures.

9.1.2 Implementation actors and processes

Actors in planning phase are the local authorities including transport and urban planners and public transport authorities. The implementation and maintenance are on the responsibility of street constructors and traffic signal planners and providers.

As to the equipment needed in the fleet the responsibility lies on transport operators but local authorities have often subsidised private companies or arranged non-profit leasing possibilities.

9.1.3 Likely impacts

The measure aims at speeding up bus travel times which is inevitably achieved as the waiting time in signals is reduced or a by-pass shortens travel time. At the same time the punctuality of the travel time increases as the predictability improves due to less hazardous crossing and travel times.

For the passenger bus priorities increases quality and reliability in terms of reduced travel time, punctuality and maybe also less stops i.e. deceleration and acceleration in addition to other positive features.

For the operator bus priorities make it possible to use the fleet more efficiently thus also reducing the cost of operation.

9.1.4 Interactions with other measures

Bus priorities are commonly used together with bus or HOV lanes and UTC as well as other management and information systems. Some of the priority measures require new infrastructure. Nowadays bus prioritisation in traffic signals and junctions is a common instrument widely used in most European cities which have problems with congestion.

9.2 Tariff system, fare levels and concessionary fares

9.2.1. General characteristics

The public transport tariff system should be fair and equitable for all users but also of simple use and enforcement for both users and operators. These requirements are often somewhat contradictory especially regarding large conurbations with several modes and a number of operators. However, the up-to-date electronic ticketing systems have made it possible to more broadly introduce unified tariff systems.

There are many possibilities to compose a tariff system. The larger the conurbation is the more complex will the system form as number of modes and operators, size of fleet, travel distances etc. increase. Commonly the tariff system comprises ticket types like:

- single tickets
- period tickets (monthly, annual, free period)
- multi trip ticket books
- special passes like tourist cards, family tickets, group tickets, etc.
- commuter travel passes
- concessionary fares for special groups and reduced price according frequency of travel

A simple tariff system should encourage people to use public transport. A single ticket system is the simplest system available but it is not equitable enough and thus unsatisfactory. In practice the simplest functional systems are sectoral or zonal even tariff systems based on the length of the trip. To keep it simple calls for a unified ticket for all modes regardless of the operator with only few fare levels and free transfers.

By the way, fare levels are the most disputable and contradictory issue affecting all actors in the society. Low fare levels attract customers but do not cover expenses of operation. If there are no subsidies for the public transport operators the fare levels must be set at such a level that the operation is profitable. If there are subsidies available the fare levels become a political issue as the subsidy is usually taken from public funds.

In addition to the overall public transport fare level the internal fare level distribution is of great importance. This encompasses the relations between different ticket types in the tariff system and all special fares. There are three main criteria for fares reductions:

1. concessionary fares for special groups like children, students, elderly, disabled,
2. reduced price according to frequency of travel commonly like period tickets, multi-trip books, commuter travel passes
3. reduced price according to time of travel like off-peak fares (but also the opposite is in use i.e. higher prices for night traffic)

9.2.2 Implementation actors and processes

The role of the actors in a transport system varies according to nation, conurbation and interurban context in question. The governmental or municipality authorities can be both administrative bodies and operators in addition to the private public transport operators, operator unions and federations.

The electronic ticketing systems have enabled more flexible and fair tariff systems. For the operators the new systems have provided a uniform database for revenue distribution.

If the operator has full responsibility on the company and service i.e. operates as a private entrepreneur he can set the prices or may co-operate with other entrepreneurs, but if there is any form of public involvement the price levels are commonly set by local politicians.

9.2.3 Likely impacts

A flexible and equitable but still simple tariff systems encourage people to use public transport.

The PT fare level has an effect on public transport demand i.e. the number of passengers using public transport. The relationship between the change in passengers due to change in fares is called price elasticity. There are a number of price elasticity studies that evidence that the short-term direct price elasticity of public transport i.e. the effect of small fare changes on the demand (the number of public transport passengers) is around -0.2 - -0.7. The long-term elasticities are somewhat higher, commonly around -1 but even higher.
There are also examples of extreme fare policies. The city of Hasselt in Belgium with 68 000 inhabitants had a reform of the bus network combined with free access in July 1997. The trial was to run till December 2000 but it turned out to be a success and is still ongoing. The number of travellers has increased 870% (the target was 380%). (LEDA 2000, http://www.hasselt.be)

9.2.4 Interactions with other measures

The tariff system together with fare levels forms a unified measure. It is also possible to integrate parking policies with tariff system by introducing a single park&ride ticket covering both the parking charge and the selected public transport ticket.

The local tariff system has an effect on the optimal fare levels as the expenses must be covered by the revenues collected and subsidies if any. The present-day electronic ticketing systems or use of smart-card make it possible to use fairly complex and individual fare levels (differentiating for person group, mode, trip length, travel time, number of trips bought or length of period etc.) without actually showing this to the customer. It is thus possible to allocate fares fairly and equally according to policies agreed and where the expenses incur.

The levels of charges and prices focused on car use have an effect on acceptable fare levels for public transport. In addition, legislative and physical measures restricting car use increase the use of public transport regardless of the cost. However, in practice there are no examples where car restrictions would have been used together with high fares. Instead, people who give up car use are recompensed by low fares as the operation is more profitable then.

9.3 New infrastructure (rail, metro, tram, terminals, park&ride)

9.3.1 General characteristics

Infrastructure provision for public transport can be categorised in two groups, the first one covers several low-cost measures like new bus lanes and better accessible bus stops, bus shelters, information displays, or raised accessible kerbs, the second one includes a wide variety of sometimes very expensive investments on rail transport and large terminals. Park and ride facilities offer a linkage between private and public transport, but may be expensive to implement into existing land use.

Infrastructure is a crucial element of the transport network, bus priority measures and interchanges such as railway stations and bus stations all need to be improved to make public transport attractive. Most measures are aimed for improving the level of service of PT. This is achieved with higher speeds, fewer delays, better interchanges and more extensive network. At the same time, some measures like bus lanes (discussed in Section 4.1) may also decrease the capacity provided for private cars.

9.3.2 Implementation actors and processes

Infrastructure provision has traditionally been the responsibility of the government, either local or national. Nowadays PPP schemes have changed this picture a bit, even though private financing usually needs specific incentive, like new market potential or increased building opportunities for developers or business. Many public transport companies lack the possibility of participating financially in such projects due to their tight financial situation. They are of course involved in the planning process, as their needs are usually the primus motor of the whole process, even though user benefit should be the main goal.

9.3.3 Likely impacts

Fast, reliable and explicable public transport system attracts new users from other modes, and may even increase mobility if accessibility is improved. New infrastructure often guarantees such improvements in level of service, as it segregates PT from other modes and enables higher speeds.

Improved stations, terminals and stops benefit also special groups, like the elderly and disabled, and herewith improve their mobility. New infrastructure is often also likely to improve the image of public transport.

Rail transport typically offers lower operation costs than bus system, which may benefit the operators.

9.3.4 Interactions with other measures

New information systems and other intelligent transport systems are often implemented in connection with new infrastructure. Service level improvements are likely when infrastructure is enhanced. Major transport schemes may also be combined with changes in tariff systems and prices.

9.4 Information provision and marketing

9.4.1 General characteristics

Information can be provided through both conventional measures and new media. Time tables, route maps etc. provide still the basic static information. Newspapers, electronic media and leaflets are used for campaigns and advertisement. On the other hand, internet, mobile media and on-line information provision have all got an important role both in information provision and marketing. Both pre-trip and real-time information are essential for all user groups.

In connection with fleet management and mobility management systems also possibilities for more accurate and actual information provision have increased. Real-time data on arrival times can be provided on screens at terminals and stops or through mobile services. Also web based route planning systems are getting common, not only pre-trip planners but real-time information systems during the trip as for the car-mode.

In order to improve the efficiency of marketing and campaigns market clusters are usually well defined. A common division into two separate target groups, regular users vs. occasional users, is a typical example of entirely different needs of marketing and information. Season-specific special offers are another way to focus marketing.

9.4.2 Implementation actors and processes

Conventional means for information provision and marketing are often responsibility of either the operators or the public transport authorities. Also public transport operators' associations and other bodies involved in the business have used their resources for campaigns, as well as environmental pressure groups and employers. When more advanced systems are used, the amount of parties involved increases. Real-time information systems require typically involvement of public transport operators, planning authorities, researchers and IT providers. In the final phase the marketing and advertising agencies often play a relevant role as well.

9.4.3 Likely impacts

The usage and share of public transport is likely to be enhanced, and as a consequence ticket income will increase. The general image and changes in public attitude towards PT are the primary aims of awareness campaigns, but focused marketing measures have more direct linkage to the use of PT. Information provision makes it easier to choose public transport, and reliable information makes travelling more convenient and less stressful for both new and customised trip makers.

Research suggests that better passenger information may contribute to a 5%-25% increase in public transport trips (UITP, 2003).

9.4.4 Interactions with other measures

Information provision interacts strongly with tariff systems and fares, new or improved services and infrastructure (like new lines and terminals), as well as with bus prioritisation schemes and means aimed to reduce car use (parking policies, capacity restraints, etc.).

Combining of pre-trip information with reservation and ticketing systems may help in financing the implementation, but such arrangements are seldom viable in urban transport. However, implementation of ITS usually provides new possibilities for information provision in general and especially for execution of general awareness campaigns for promoting public transport also in urban context.

9.5 Legislation on emission standards

9.5.1 General characteristics

Emission standards are regulated on national and nowadays on European level, so properties of new vehicles and condition of older fleet can not be decided on local level. However, when local public transport is tendered, it is possible to use emission levels of the buses as one criterion when the tenders are evaluated.

9.5.2 Implementation actors and processes

Authorities buying the transport services, PT operators and environmental authorities are involved when emission standards are applied. Also national bodies may be interested in such process, especially when free competition has to be ensured.

9.5.3 Likely impacts

Strict requirements may increase the cost of operating the PT system, but it also has certain impact on pollution levels and sometimes also on energy consumption and noise. Public awareness impacts may extend to both passengers and car users.

9.5.4 Interactions with other measures

Emission standards are quite autonomous as a policy measure, but they might be the base for different taxation of PT vehicles according to their emission category, as well as for different prioritisation of PT low emission vehicles in residential areas.

9.6 Taxes and subsidies

9.6.1 General characteristics

The total taxation affecting public transport is comprised of many different kind of taxes:

- Taxes on operators – company taxation
- Vehicle tax on purchasing, tolls
- Fuel tax
- Yearly taxes based on vehicle type (emission tax)
- Discrete taxes
- VAT on services and tickets etc.

Subsidies to operators are one of the most common measures to enhance public transport. Public funds may be used to reduce ticket prices or to increase transport services. Regional ticket systems are often supported with subsidies, and publicly owned transport companies may receive public funding directly from municipal or regional budgets. Increase of routes or departures is often directed to areas with low and medium demand.

9.6.2 Implementation actors and processes

Most of the taxes are governmental or collected by the municipality. In urban context public transport is commonly exempt from tolls and other special charges.

In urban areas municipalities are the main contributors of subsidies to operators, but in some countries also national or federal sources exist. The organisation and processes depend on how the money flows are planned and on how the clearing is arranged. Public transport operators may receive the subsidy directly or via purchase of services.

If the funds are used to reduce fares they may also be directed to municipal or regional public transport organisations in charge of the local system.

The funds may be raised either through general taxation (national or local), specific taxes (like additional fuel taxes) or charges (like road tolls). Actually, financial barriers are typically the only restriction for the use of subsidies, otherwise most actors accept this measure.

9.6.3 Likely impacts

The taxation policy affects the characteristics of the fleet and the cost of operation and thus fare levels as well. There are many aspects that can be favoured by the policies affecting the characteristics of the fleet: reduce emissions and other burden on the environment, reduce noise, increase comfort for the passengers, etc.

Subsidies allow the operators to apply lower ticket prices or better public transport services, which both encourage the use of public transport and are likely to reduce private car use. Subsidies may also make it possible to serve areas of low transport demand, which would otherwise be left without public transport services. Thus this measure is also likely to enhance equity.

9.6.4 Interactions with other measures

Taxation policies are complementary with subsidies allowed. Taxation of cars and other markets may be ear-marked for use for public transport subsidy and thus have a direct impact. Also taxes on public transport itself can be ear-marked for supporting public transport only. Subsidies interact especially with fares, tariff system and service levels.

9.7 Service level requirements (operating time, frequency, accessibility, special services etc.)

9.7.1 General characteristics

If the objective is to have a high public transport share and reduce car use in an urban area the public transport system must offer a competitive means of travel to the car. If the public transport system is coordinated or subsidised by public authorities there commonly are public requirements concerning the service level, time of operation, frequency, accessibility, quality of vehicles, tidiness of vehicles, stops and terminals as well as for arranging special services for those who cannot use the normal system. If a public transport operator is totally independent, the requirements may not be public but also in this case the company certainly has minimum requirements for internal use but of course these cannot be used as policy measures.

Service level requirements commonly cover at least:

- Operating time

- Minimum frequency during different times of day on weekdays and weekend
- Accessibility in terms of coverage of public transport services, distance to nearest stop, number of transfers to main centres and nearest services etc.
- Quality and tidiness of stops and terminals, shelters and other equipment at stops etc.
- Quality and tidiness of vehicles, such as easiness to board and alight, comfortable seats, holders for standing passengers etc.

9.7.2 Implementation actors and processes

The search for improved quality and continuous improvement must be a shared objectives by the authorities and operators involved in the systems. The bodies should be driven by an obsession: to increase the value of public transport. This implies recognition at the users and the citizens as being in a central place in the system, give them the right to chose freely their travel mode and to organise their travel easily, without having to consider the geographic and functional frontiers between authorities or the different nature of operators. (Quattro, 1998)

Quattro suggests to use quality and quality management to attract customers by offering services which compete with the private car. It recommends to consider “quality” management as a continuous search for better service and permanent progress in organisation, rather than as the pursuit of a rigid and specific level of quality.

Quattro indicates that whatever the regulatory regime for urban public transport, tools exist to stimulate authorities and operators to implement successfully the reach for quality in the public transport service provided to the users and the citizens. By appropriate quality tenders and quality contracts, this “obsession” could be encouraged and positive results should follow.

9.7.3 Likely impacts

The aim of setting service level requirements is to guarantee the passengers a clearly stated minimum level of service, safety and security. The aim is to have customers that are satisfied and loyal to the system and also encourage new customers. In many cities the target is to offer everyone an equal opportunity for mobility by public transport regardless of car ownership. Example and present practice show that the market respond positively to the realisation of improved quality measures. (Quattro, 1998)

9.7.4 Interactions with other measures

The service level is an essential part of the public transport system as a whole. Together with the tariff system and fare levels it influences the customers’ attitude and conception of the public transport system. In addition, good information provision on the system – efficient and sufficient but simple and clear – promotes public transport.
A high public transport service level is essential for customer satisfaction, especially when measures restricting car use are introduced.

9.8 Special services

The Service Bus is a special public transport service for people that are unable to use conventional public transport services but need short walking distances and direct transport over short travel time: senior citizens, walking-impaired and disabled persons, parents with infants, young schoolchildren, et al. Presently service buses are in service in many cities

The Personal Bus service incorporates an interactive Demand Responsive Transport (DRT) system where the routes and times are not set, but vary according to the needs of the patrons. In some cities the trial for a DRT system was done by the SAMPO project (SAMPO, 1997). Most of the trials have been successful and the systems have been further developed. The prevalence of mobile phones has made the calling easier.

Using suitable vehicles also other transport obligations of the municipality (such as taxi services for people that are unable to use conventional buses and school transport) can be combined with the service lines or the DRT-systems. The systems are often economically profitable for the municipality, because very expensive special driving arrangements can be reduced.

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