

ESTIMATING ANCILLARY IMPACTS, BENEFITS AND COSTS OF GREENHOUSE GAS MITIGATION POLICIES IN THE TRANSPORT SECTOR

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1. Introduction

This is a relevant topic because of three reasons. First there is a strong growth of CO₂ emissions in the transport sector. In the EU, it is expected that in 2010, the CO₂ emissions in the transport sector will be 40% higher than in 1990. In the US, growth rates could be 28% or higher [De Cicco & Mark, (1998)]. In developing countries and newly industrialised countries growth rates will be much higher as transport activity tends to grow faster than GDP in the industrialisation phase. These high growth rates make that the reduction of greenhouse gasses in the transport sector has become a priority for many policy analysts.

Second, there is no unanimity at all on the most appropriate policies to reduce GHG emissions in the transport sector. Mostly car use and air traffic are targeted but the type of policy instrument to be used remains unclear. Proposals include higher fuel taxes, speed limits, gas guzzler taxes on vehicles but also subsidies for mass transit.

Third, there are other important externalities in the transport sector (traffic accidents, congestion) and therefore the consideration of ancillary benefits could have a large impact on the policy choice.

It is not our intention to survey the whole field of transport and the environment ². Our aim is restricted to the analysis of policies that have been proposed to reduce GHG emissions. In section 2 we show on the conceptual level what are the ancillary benefits and costs that can be expected from different types of policies in the transport sector. It will become clear that the measurement of external costs of transportation is one of the key elements to determine ancillary benefits. The problems in estimating external congestion, air pollution and accident costs are dealt with in section 3. In section 4 we survey some studies that try to determine the costs of GHG reduction and the role of ancillary benefits. We distinguish between studies in the EU, the US and Developing Countries. In section 5 we conclude and sum up research priorities.

¹ I thank the organizers A.Krupnick, D.Davis, my discussant, P.Crabbe and other participants of the workshop for their comments on a previous version of this paper.

² For a survey, readers can consult Bohm P., Hesselborn P-O, (2000) or Calthrop E., Proost S.(1998),

2. Conceptual issues: definition of private, external, social and ancillary benefits and costs of policies in the transport sector

We use a simple graphical model of the transport market to define the most important concepts on costs and benefits³. Later this illustration will be used to define the ancillary benefits of GHG reduction policies in the transport sector.

2.1 A graphical approach to ancillary benefits

We use a graph of one transportation market with two externalities: congestion and others (greenhouse gasses, air pollution, accidents etc.). We take congestion because it is the most difficult to understand and the most controversial. The transportation market we select is the use of a motorway between two cities during the peak period. We assume that the road infrastructure and the location of households and firms are fixed.

2.1.1 A transport market

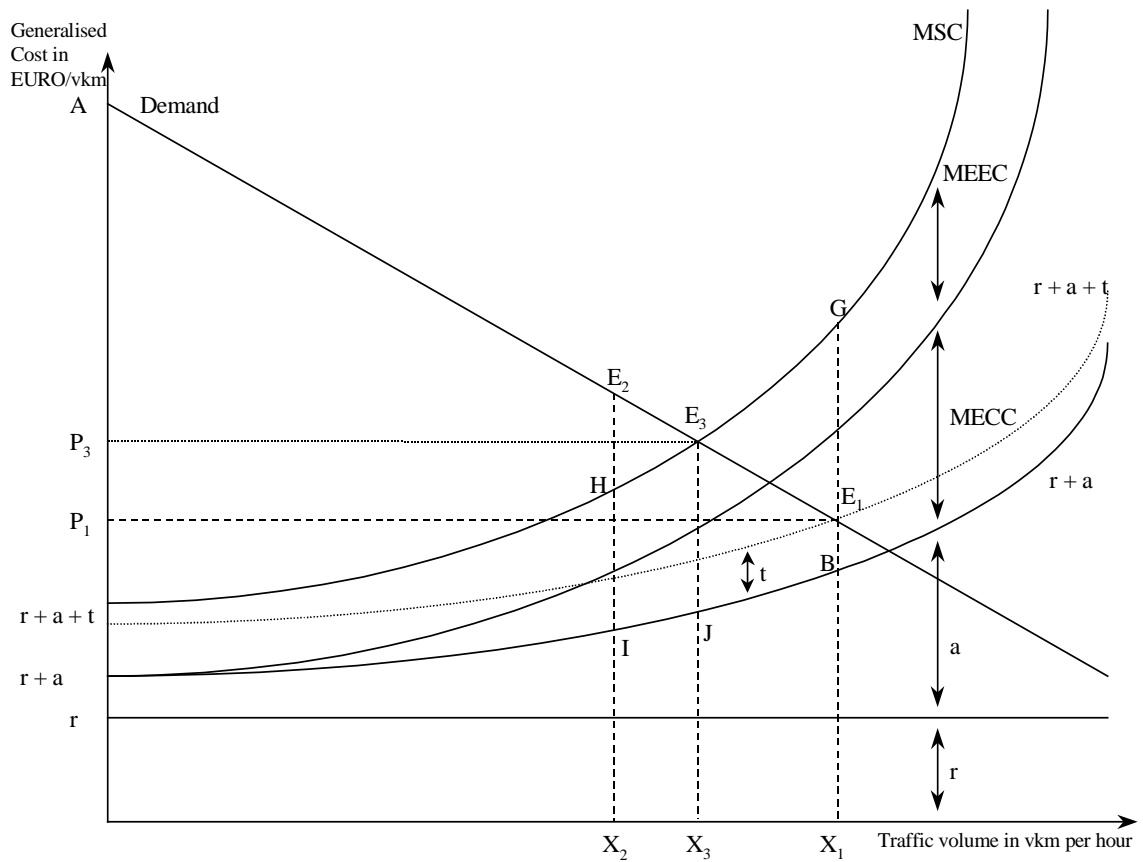
Consider the market for car km on a specific road link between two cities as depicted in Figure 1. This figure represents the market for car km in one particular period (peak) with one particular type of car (small petrol car with catalytic converter) on a road infrastructure with given capacity.

On the horizontal axis we represent the volume of car use (vehicle kilometre per hour). On the vertical axis we represent the generalised cost of car use. This generalised cost will equal the sum of the money cost (EURO/vehicle kilometre) paid by the car user plus the time cost needed per car kilometre.

The *demand function* expresses the marginal willingness to pay for car use at each volume of car-kilometres. The surface under the demand curve is thus a measure of the total benefits of car use: at a very high price only the strictly necessary car km would be demanded - as generalised costs drop, more and more households are ready to use the car for all types of purposes.

³ We use material from De Borger & Proost (2000) here. A more advanced treatment can be found in Small (1992)

Figure 1. A transport market



In this market, the volume of car use will be determined by the generalised cost of car use. Take any point on the vertical axis, the corresponding volume of car use on the horizontal axis is given by the demand curve: at this level of car use, the marginal willingness to pay of the last car user equals the generalised cost. Obviously, the volume of car use depends on many other elements as there are: prices of other modes and other goods, speeds and quality of other modes, location, income, composition and social attitudes of the household. All these other elements are kept fixed here.

In order to determine the equilibrium volume of car use we need to determine the cost for the user, we call this the *generalised private cost of car use*. The generalised private cost of car use consists of three elements: the resource costs, the taxes or subsidies and the average time cost. The resource costs equal the marginal production costs of the different inputs needed to use a car: fuel cost, maintenance cost, tyres and physical vehicle depreciation. It is represented by the line r in Figure 1. The resource costs plus average time costs are represented by the curve $r+a$. The average time cost increases when the volume of car use increases due to congestion: speeds drop and all drivers have higher time costs. When we add taxes on car use t (aggregate of taxes on fuel, maintenance, registration, etc.) we obtain the generalised private cost of car use (dotted line $r+a+t$). In figure 1, this means that the equilibrium volume of car use is X_1 and the generalised price equals P_1 . This is the equilibrium we observe on the transport market.

2.1.2 External costs and taxation of transport

There can be external costs in this equilibrium. *External costs* are costs that are generated by a car user but not paid by him. The first externality is the marginal external congestion cost. The marginal external congestion cost is the cost of the additional time losses imposed on others by one extra car user.

This cost (MECC in Figure 1) is steeply increasing when we reach the capacity of the road network because of two reasons. First, adding one car decreases more and more the speed. Secondly, when there are more cars on the road, the decrease in speed will affect more cars. The marginal external congestion cost in Figure 1 corresponds to the increase in the average time cost curve times the volume of car use. It is important to recognise that, although every car user experiences congestion (higher time costs) himself, he does not pay for the time losses caused to other car users (the external part of the congestion costs).

We add a second external cost on top of external congestion costs: this can be air pollution, noise, accidents etc. (distance MEEC in Figure 1, taken more or less constant but this need not be the case).

The *total marginal social cost* of car use is now given by the sum of resource costs, average time costs, external congestion costs and other external costs. Taxes are excluded from the total marginal social cost. Taxes are a private cost but no cost at the level of society whenever taxes are returned to the households in an efficient way what we assume here. The marginal social cost includes all costs of car use. The optimal volume of car use would be reached when the marginal willingness to pay for the car use equals at least this social marginal cost. This means in Figure 1 that X_3 is the optimal volume of car use: in this point the demand function (or marginal WTP curve) crosses the marginal social cost curve. The corresponding optimal generalised price equals P_3 . This equilibrium can be reached by using an optimal tax E_3J . This tax equals the difference between the marginal social cost and the private cost of car use (before taxes). The efficiency gain of implementing this optimal tax equals the area E_3GE_1 : the excess of social marginal costs over the value of car transport to the user as given by the demand function.

In the equilibrium shown in Figure 1, the total marginal external costs are only *internalised* partially: the tax paid per vehicle km is smaller than the total marginal external cost. The total tax paid per vehicle kilometre is too small. This is not the only problem. In general the tax paid is also not well tailored to the type of externality. This is important because there are different ways to decrease the level of externalities. First one can adapt the volume of car use and this affects the size of the external congestion cost but there is also the choice of vehicle type (more or less polluting), the driving style etc that all affect the size of the external air pollution, noise and accident costs. When a regulation forces all car drivers to use a cleaner car this will increase the manufacturing cost of cars (r will increase in Figure 1) but the size of the marginal external air pollution cost will decrease (MEEC in Figure 1 becomes smaller). A good air pollution regulation will make sure that the sum of the marginal external air pollution cost and the additional manufacturing cost of cars is as low as possible. When a good air pollution regulation decreases the marginal external air pollution costs, the optimal toll on car use decreases and the optimal level of car use could increase. This illustrates that policies affecting the volume of traffic (tolls, fuel taxes, road infrastructure,...) need to be coordinated with the policies affecting the type of vehicles used.

In our graphical example, the transport market had too low charges, this is a typical result for congested areas where the main tax policy instrument (fuel tax in the absence of time specific tolls) is unable to correct for the high external congestion costs. There exist many other transport markets (low congestion traffic on rural roads in countries with high fuel taxes) where the tax level is too high. In the latter case, car transport use is discouraged too much as in the equilibrium, the marginal WTP for extra trips is still higher than the marginal social cost.

One can raise the question *why we do not have a more efficient tax system* so that charges and taxes equal systematically the marginal external costs? There are several reasons one can think of. A first explanation is the cost of a sophisticated tax system: making cars pay the proper external cost requires pricing differentiated by space and time, by driving style, vehicle type etc.. This is a very costly operation and therefore most countries resort to less expensive tax systems on fuels and vehicles that will overcharge some markets and undercharge other transport uses. A second reason is probably the complexity of the political decision process that makes that a growing problem like congestion is tackled too slowly because the construction of new roads and the increase in user charges are both unpopular decisions.

Figure 2. A transport market with capacity extension

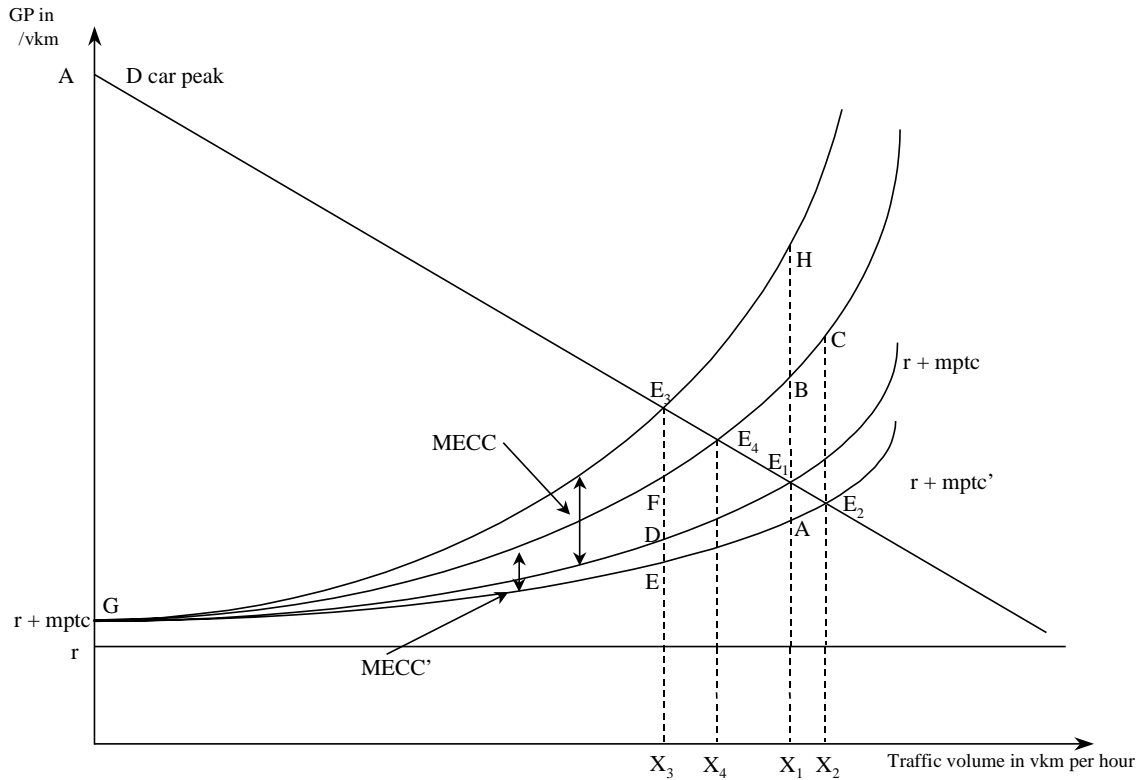


Figure 1 was constructed under the assumption that the road capacity was fixed. The road capacity determines the average time costs and is therefore an important policy variable to regulate the total quantity of transport. This is certainly the case in developing countries where the question is not to have any road extension or not but the pace at which the road network is extended and how to finance the investment. The effects of *an extension of the road capacity* can be discussed using Figure 2 that is of the same type as Figure 1. To simplify the exposition we assume that there are no taxes on car use. In the absence of taxes and before extension of the road capacity, the equilibrium was X_1 . Important external congestion costs exist. We can now check what is the effect of a road extension. The extension of the road capacity means that the average time cost function and the private generalised cost (dotted curve in Figure 2) shift downwards as well as the marginal external congestion cost curve (dotted social marginal cost curve in Figure 2). The new equilibrium car use is now X_2 . Note that speed is increased but the increase in speed is much less than expected as higher average speed attracts new traffic ($X_2 > X_1$) because the generalised price went down. It would have been better if there had been no increase in traffic as the newly generated traffic decreases total economic efficiency by the area BCE_2A . The net benefits of road extension will be the decrease in social costs for the existing traffic (area GHB) minus the net efficiency costs of induced traffic (BCE_2A). This net benefit has to be computed for every future year and the discounted sum of these net benefits can be compared to the investment cost including external environmental costs associate to the infrastructure construction. When the net benefit is larger the investment is economically efficient.

It is important to realise that different investment decisions need to be taken when pricing of traffic is more efficient. Starting with optimal pricing in equilibrium X_3 the same road extension would now lead to the new equilibrium X_4 . Again new traffic is generated but the optimal pricing policy makes sure that this new traffic is justified from an efficiency point of view: the marginal WTP of the attracted traffic is larger than the social marginal cost. The net benefit of a road capacity extension is now smaller: $GE_3 F + E_3 E_4 F$. In developing countries where the growth of demand is high, infrastructure extension is an important component of transport policy. The need for infrastructure extension and the corresponding induced demand reactions can be contained if an effective pricing policy is pursued. Correct pricing of road use tends to reduce the need for infrastructure extension.

A frequent question is whether external cost pricing (or short run marginal cost pricing) will cover the investment costs? If investment policy is optimal, and if tolls equal at least the marginal external congestion costs, the revenue of the toll will equal the marginal infrastructure extension cost. If this cost is constant, tolls will at least pay for the investment cost. This also implies that, given optimal pricing and investment, the level of congestion is not zero⁴.

2.2 *Policies to reduce GHG emissions and the definition of Ancillary benefits*

Ultimately we are interested in computing the welfare costs of CO₂ reduction policies in the transport sector. The different costs of policies can be illustrated using Figure 1 and 2. We discuss briefly the following policies: vehicle fuel efficiency standard, fuel tax, transit subsidy, transport infrastructure policies and location policies. For each of these policies we describe the expected effects and the costs and benefits (excl. climate change benefits).

We define ancillary benefits as the benefits of greenhouse gas reduction policies other than the climate change benefits. This definition only makes sense when we know what is included in the costs of a greenhouse policy. We define as cost the direct resource costs of the emission reduction policy that the economic agents have to bear. Using this type of definition means that ancillary benefits will only exist whenever there exist non-internalised externalities other than climate change [Markandya, Krupnick, Burtraw,(2000)]⁵. We will use this definition throughout this text. There exist other definitions but discussing them would not be very interesting. In the end what matters is to include in the net cost of GHG reduction policies, all costs and benefits associated to this policy other than the Climate Change benefits themselves. This is the basic requirement for any Cost-Benefit Analysis.

⁴ For a pioneering numerical illustration of the relation between investment and pricing one can consult Keeler and Small (1977).

⁵ We refer to Markandya, Krupnick, Burtraw, (2000) for a more thorough treatment of second order effects. One of these important second order effects are the tax recycling effects that can be particularly important in the (highly taxed) transport sector. Interested readers can consult Parry and Bento (1999) and Mayeres and Proost (1997 and 2000).

2.2.1 Vehicle fuel efficiency standard

This is one of the most frequently used policies. A fuel efficiency standard will make new cars relatively more expensive⁶, in the long term this will increase the costs of car use. In Figure 1, line r will increase but the private generalised cost ($r+a+t$) will increase less when there are important fuel taxes because the more fuel efficient car saves also fuel taxes. In total, this will result in lower car use and smaller CO₂ emissions per vehicle kilometre

The costs and ancillary benefits of this policy are summarised in Table 1.

Table 1. **Costs and ancillary benefits of vehicle fuel efficiency standard**

	<i>Suppressed traffic</i>	<i>Remaining traffic</i>
Costs of policy	<ul style="list-style-type: none"> • Lost consumer surplus • Lost tax revenue 	<ul style="list-style-type: none"> • Increase in resource costs of vehicle use
Ancillary benefits	<ul style="list-style-type: none"> • Saving in external air pollution, noise and accident costs • Saving in external congestion costs (= reduced time costs of remaining traffic) 	<ul style="list-style-type: none"> • Decrease in external air pollution costs

The most important ancillary benefits will probably be the savings in air pollution costs (other than CC) for the remaining traffic and the savings in external congestion costs through the reduction in the traffic level. This means that the effect on traffic volume will be one of the major determinants for ancillary benefits. Ancillary benefits correspond here to savings in external costs (other than climate change). If external costs would have been perfectly internalised by taxes, the lost tax revenue for suppressed traffic will equal the savings in external costs for suppressed traffic and Table 1 is simplified. The only ancillary benefit that remains is the decrease in external air pollution costs. In general taxes will not internalise external effects perfectly and will overshoot external effects on some markets and be lower than external effects on other markets.

2.3 Fuel tax policy

Conceptually this policy is close to a fuel efficiency policy but the order of magnitude of the different effects will be different. To save the same total quantity of CO₂ as with a fuel efficiency standard, a fuel tax policy will count less on the improvement of the fuel efficiency and rely more on the reduction in the volume of traffic. The reason is that the car driver now also pays more for the remaining fuel use. This leads to costs and ancillary benefits that are different from those of a fuel efficiency standard. Compared to table 1, the suppressed traffic effect becomes more important so that the ancillary benefits will consist more in saved external congestion costs than in saved air pollution costs.

⁶ We assume a proper functioning of the car market so that adding an extra technical requirement can only increase the price of a car.

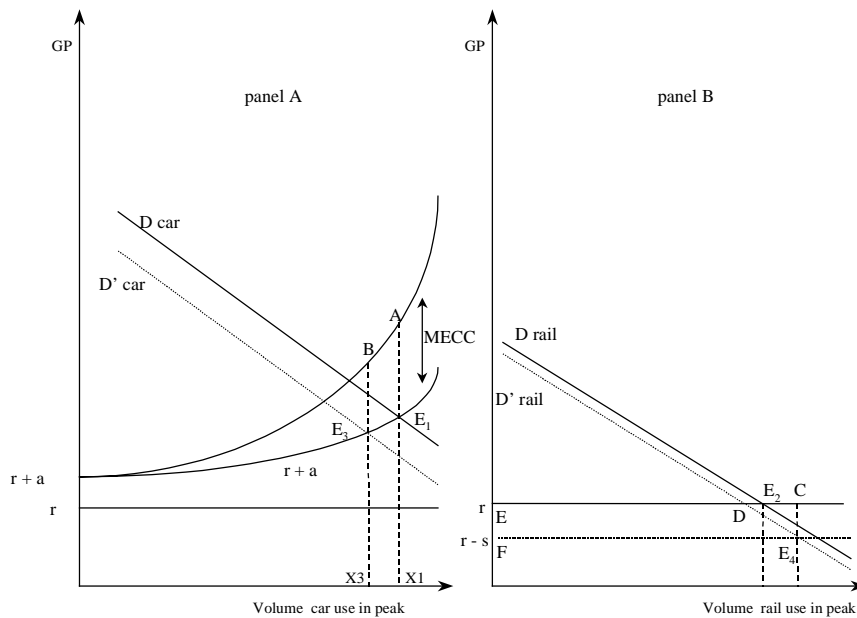
2.4 Public transport subsidy

The subsidy to public transport as a greenhouse gas reduction policy is in general motivated by the better fuel efficiency per passenger km of public transport.

The interactions to be taken into account are illustrated in Figure 3. We start in Panel A of this figure with a given volume of car use X_1 that is too large: there is an important marginal external congestion cost (A E_1). In Panel B we have a rail service where the price equals the marginal cost r . The equilibrium is E_2 . We can simulate the effects of a subsidy s to rail in Figure 3. The subsidy decreases the price of the rail mode to $r-s$. This will make the demand curve for car use shift to the left (D'): for the same generalised cost of car use there will be less car users because some of them prefer the train. When taxes on the car market remain unchanged (to keep it simple we have assumed no taxes here), the external congestion cost decreases to BE_3 . Because the equilibrium volume of car use decreases to X_3 there will be a decrease of the generalised cost of car use (the average time cost decreases). The decrease in the generalised cost of car use will produce a shift to the left of the demand function of rail use (D'). The ultimate equilibrium is E_3 for car use and E_4 for rail use.

In order to compute the net welfare gain of this subsidy one needs to balance the welfare loss on the rail market with the welfare gain on the car market. There is an efficiency loss on the rail market because some users now make trips that do not cover the marginal resource cost of rail trips. There is a welfare gain on the peak car market because the number of car trips for which the willingness to pay is lower than the social marginal cost has been reduced.

Figure 3. Effects of subsidies to public transport



The costs and ancillary benefits are summarised in Table 2.

Table 2. **Costs and ancillary benefits of a public transport**

	<i>Rail market</i>	<i>Car market</i>
Cost of policy	<ul style="list-style-type: none"> • Efficiency loss on rail market 	
Ancillary Benefits	<ul style="list-style-type: none"> • Increased external costs of rail market 	<ul style="list-style-type: none"> • Saving in external air pollution , noise and accident costs due to suppressed volume • Saving in external congestion costs (= reduced time costs of remaining traffic) due to suppressed volume

2.5 *Modal shift policies in the freight sector*

The idea is similar to the subsidies to public transportation. Now the subsidies are given to modes like rail and inland waterways that have in general lower GHG emissions per ton km transported than trucks and airplanes. As many of these markets have important external effects, the ancillary benefits or costs can be important.

2.6 *Road investment policy*

Not to extend roads can be considered as an instrument to contain the growth of traffic and to reduce the emission of GHG (cf. our Figure 2). Compared to the situation with road capacity extension, there will be costs and ancillary benefits associated to the remaining traffic and the suppressed traffic. There will be suppressed traffic and remaining traffic and the costs and ancillary benefits are listed in Table 3.

Table 3. **Costs and ancillary benefits of not extending the road capacity**

	<i>Suppressed traffic</i>	<i>Remaining traffic</i>
Costs of policy	<ul style="list-style-type: none"> • Lost consumer surplus • Lost tax revenue • Saved investment cost (benefit) 	<ul style="list-style-type: none"> • Increase in average time costs
Ancillary benefits	<ul style="list-style-type: none"> • Saving in external air pollution , noise and accident costs • Saving in external congestion costs (associated to average time cost function with road extension) 	<ul style="list-style-type: none"> • Increase in other external air pollution costs ?

2.6.1 Location policy

Transportation is the result of passenger trips between home, school, job and leisure locations and of freight transport between the producer and user of inputs and outputs. The most obvious way to reduce CO₂ emissions, is to reduce the need for transport flows through relocation of activities. This idea looks simple but analysing its implications fully is a complex undertaking. The problem is that higher concentration of activities saves emissions but can also imply economic costs. These can consist of loss of specialisation (higher overall production costs) and of an increase in other external costs. Noise, air pollution and industrial risk impacts can be larger in more concentrated locations.. In a recent survey on urban spatial structure, Anas, Arnott and Small (1998) find that urban economics has not yet clear views about the determinants of city size and optimal city planning.

Location policy is a potentially very important instrument; certainly in developing countries where urban growth rates are high. A minimum requirement for a good location policy is that there is close coordination in land use policy and in the construction of public transport capacity. Light rail or metro systems only make sense for very high densities of population.

3. Problems in the estimation of ancillary benefits

Ancillary benefits of GHG reduction policies in the transport sector will consist mainly of two types: time savings for remaining road traffic due to a decrease in road transport volume and savings of external costs (other than congestion) due to either a reduction in transport volume or due to a decrease in the intensity of external costs per vehicle kilometre for remaining transport flows.

We discuss briefly⁷ the estimation problems for congestion gains, traffic accidents, and conventional air pollution. We add a fourth problem: the treatment of resource costs that are not paid by the user.

3.1 Reduction of congestion

Any reduction of transport volume for a congested mode brings extra time benefits for the existing users. Estimating these benefits raises two issues.

The first is the estimation of the *value of time*. This issue was important for transport experts and nowadays there exist many studies using revealed preference and stated preference techniques. They give a range of time values for different trip purposes and comfort conditions. Time values differ according to purpose, comfort, income level etc.. Although there exist wide differences in time values, these differences can be rationalised and values of time should not be considered as a major difficulty.

⁷ More elaborate discussions of marginal external costs can be found in Jansson (1994), Calthrop & Proost (1998), Green, Jones, Delucchi (1997), Mayeres, Ochelen, Proost (1996), Maddison *et al.* (1996).

The second problem is the inclusion or not of *schedule delay costs*. There are two competing formulations for a congestion cost model. The first model uses a speed-flow relationship where adding extra traffic volume decreases average speed that can be translated into time losses. The second model is the bottleneck model (Arnott, De Palma, Lindsey (1993)) where the peak period is of variable length: once the road capacity is reached, drivers incur queuing costs (time losses) but also schedule delay costs. The second type of model will tend to generate much higher congestion costs. Of interest is that most formulations tend to use rather the first type of formulation and could therefore underestimate the congestion problems.

3.2 *Traffic accidents*

The external accident costs are probably the most controversial topic in the estimation of the ancillary benefits. Imagine that we are able to reduce car use. Are there any savings in traffic accident costs to be included in the ancillary benefits? There are two sources of benefits (or savings in external costs): first the reduction of external accident costs for constant accident risks and secondly the change in accident costs due to the change in accident risks.

When we keep the average accident risk constant, a reduction in the volume of traffic will save accident costs. This can only be considered as a net benefit if the driver did not already take these into account. A driver takes into account the accident costs by two mechanisms: he takes into account his own accident costs (including the valuation of relatives and friends for his loss of live or injury) and his insurance premium. If his insurance premium covers all average accident costs and is related to his driving decisions, the average accident costs are taken into account by the user. Insurance premiums do probably not pay for all accident costs: some “cold blooded” costs as there are police costs, medical emergency services etc. are probably not paid and it is not clear what type of subjective value of life and injuries⁸ is taken into account. Secondly, insurance premiums are mostly an annual payment unrelated to the number of km driven. The “pay at the pump” advocates conclude that insurance premia are not taken into account at all by drivers (Kavalec & Woods (1999)). This is not fully correct: annual insurance payments still determine the car ownership decisions and more and more insurance contracts link the premium to the personal accident record and therefore to the annual mileage. Obviously, if there is no car insurance at all as is probably the case in some developing countries, traffic accident costs can be an important component of ancillary benefits.

Assume from now on that the average accident cost is paid but that the average accident risk increases with the traffic volume. In this case drivers pay average costs and not marginal costs and any reduction of traffic volume generates an ancillary benefit equal to the difference between marginal and average accident cost. Initially, several authors (Vickrey,(1963), Newbery (1990)) used a model with this feature. Recent empirical studies of the relationship between traffic volumes and accident risks (Dickerson *et al.*(2000). show that average accident risks stay more or less constant at low to medium traffic flows and increase at high capacity utilisation rates, an externality may exist there but this still needs to be corrected for differential impacts of the volume of traffic on the type of accidents. Accidents may become less severe at high congestion levels.

⁸ The estimation of the subjective value of loss of life and limb remains an important research topic in economics as the traditional techniques (CVM, RP) don't work that well

3.3 *Air pollution*

Air pollution is a traditional example of external costs. The main difficulties in estimating saved air pollution costs are the dose response relationship and the estimation of the value of years of life lost and of health problems. This issue is treated in depth in a companion paper for this symposium: Krupnick, Davis and Thurston (2000).

3.4 *Other unpaid resource costs*

Most studies assume implicitly that all traditional resource costs (for a car: car, fuel, maintenance, parking and so on) are paid by the car user. This need not be true. For cars a common counterexample is free parking offered by employers or shopping centres. Whenever more employees take mass transit to go to work or more people go shopping by bus as part of a GHG reduction policy, there is a saving of parking resource costs that could be counted as ancillary benefit. The story is more complicated than this. Making people pay for their parking costs may actually increase distortions on the labour market (because one discourages labour supply even more) and there may be high transaction costs associated to billing for parking.

Mass transit raises other challenges. In some countries, users don't pay anything or less than the marginal social cost. The marginal social cost may itself also be difficult to compute because of economics of density in public transport [Small (1992)].

4. *Climate change policy studies in transport: how important are the ancillary benefits?*

We review some of the existing studies by geographical area. An approach by area is needed because there are major differences in the present transport policies. As we had an easier access to recent unpublished European studies they receive more emphasis. This could also reflect a stronger interest in GHG emissions in the transport sector in Europe compared to the US. Very few studies are available for the Developing Countries. It is probably in these countries that exist the highest needs for transport and environment policy studies.

4.1 *Europe*

European transport policies are characterised by high densities in urban areas, relatively low mobility, high fuel taxes and a well-developed system of mass transit (rail, metro, bus). The last 5 years, the European Commission has been advocating the use of better transport pricing policies. Different European research consortia (PETS, TRENEN-II, AFFORD) have studied the potential benefits of marginal social cost pricing. These projects together with a study by Koopman (1995) will be our main sources.

In the TRENEN II consortium (De Borger and Proost 2000), the expected private costs of car use and of other modes are compared to the social marginal cost of using these modes. This is the type of information we need to determine in what type of transport equilibrium we are now (in terms of Figure 1: are we in equilibrium X_1 or X_3 ?). The comparison of private prices and social costs will tell us also what are the major types of non-internalised external costs and these are at the origin of ancillary benefits. The social marginal cost includes all resource costs together with the external cost of congestion, accidents, noise, climate change and other air pollutants. The external cost of air pollution was extrapolated from EXTERN-E results (Bickel *et al.*, (1998)) and includes climate change benefits. Figures 4 and 5 compare for different cities and non urban areas, the cost per car kilometre of a private user that does not have to pay for his parking spot (most drivers don't) and the marginal social cost expected for 2005 when policies are unchanged. Figure 4 deals with the peak period. For each area, two bar charts are shown. The first bar represents the private car user costs that consist of the sum of the resource cost (production cost of car, maintenance and fuel cost), the price of parking (zero by assumption here), the taxes and the time cost. The second bar chart represents the marginal social cost of car use that consists of the sum of resource costs, parking resource costs and the marginal external costs. Figure 4 shows that there is an important discrepancy between the private users' price (left bars) and the social marginal cost (right bars) in the peak period for cars. The major problems are the unpaid resource cost of parking in urban areas and the external congestion costs. Similar graphs exist for public transport and freight transport. Almost all modes of transport are underpriced in the peak, some of them because of the very high external costs, others because they are heavily subsidised. The discrepancy is much less pronounced in the off peak period where car use is sometimes overtaxed.

Figure 4. Peak car reference prices and costs (expected for 2005)

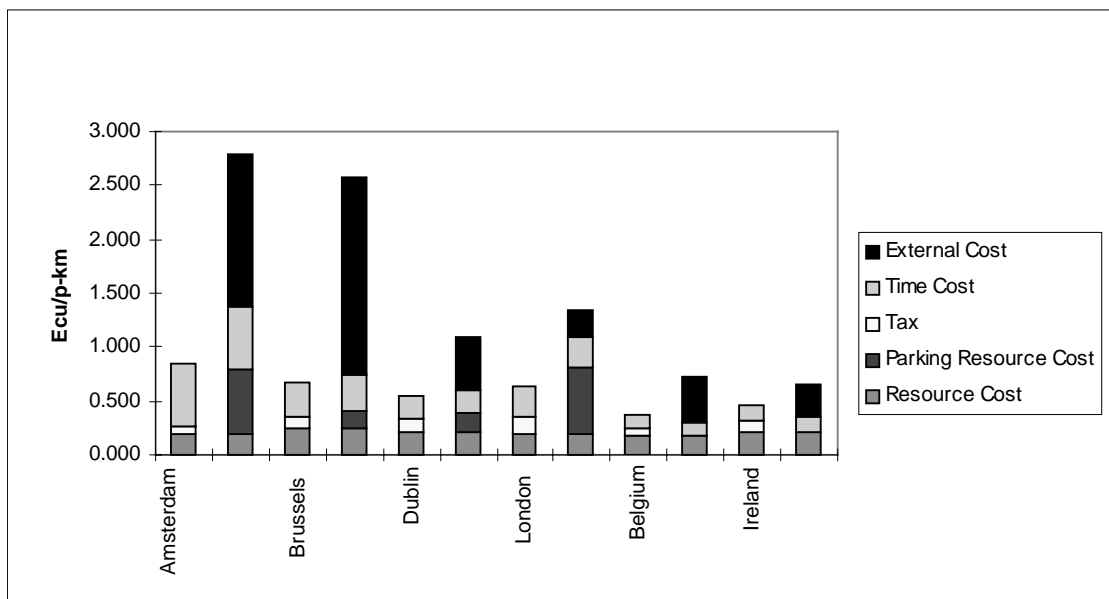
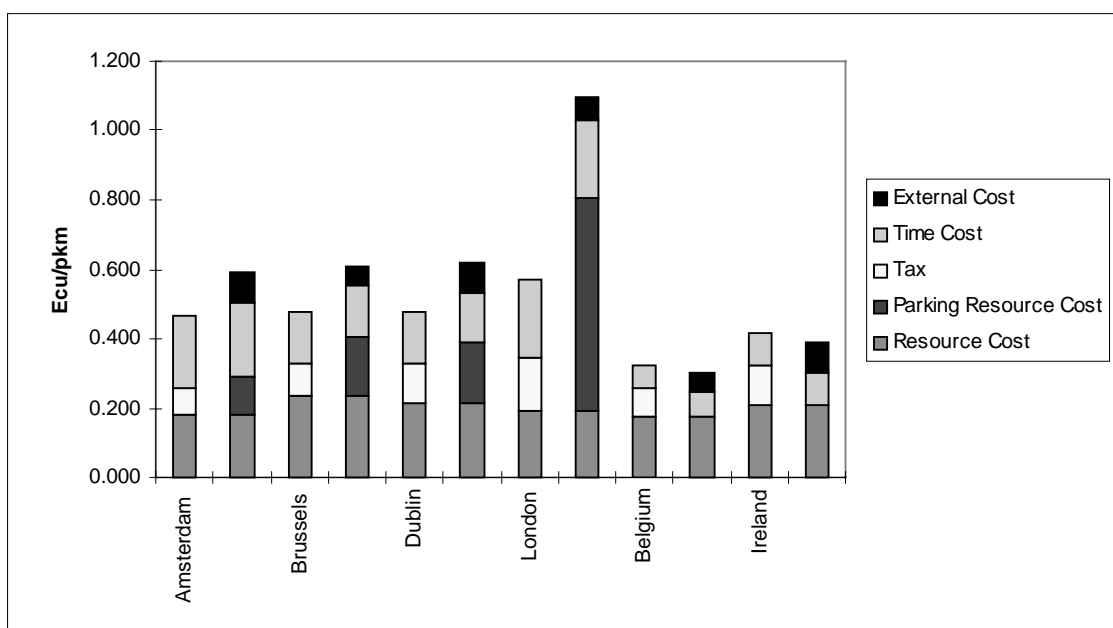


Figure 5. Off-peak car reference prices and costs (expected for 2005)



We analyse here more in particular the case of Brussels. The structure of the marginal external costs is given in Table 4 (Proost & Van Dender (1998)).

Table 4. Structure of marginal external costs for a small car in Brussels in 2005

in EURO/Vehkm	Gasoline		Diesel	
	Peak	Off peak	Peak	Off peak
Air pollution	0.004	0.004	0.042	0.026
Accidents	0.033	0.033	0.033	0.033
Noise	0.002	0.008	0.002	0.008
Congestion	1.856	0.003	1.856	0.003
Total	1.895	0.047	1.932	0.068
Tax	0.12	0.11	0.08	0.07

One can see that the price inefficiencies are dominated by external congestion costs that only appear in the peak period and that, as regards air pollution, diesel is the major problem because of the health problems attributed to PM₁₀. The low air pollution costs are the result of the implementation (by 2005) of many recently decided regulations on car emissions in the EU. For CO₂ a damage estimate of 25 EURO/ton of CO₂ is used. Appropriate instruments can probably reduce each of the external costs but it is already clear that the congestion issue will drive most policy assessments.

In the end, the inefficient transport market is the result of wrong tax and pricing policies. The TRENEN – II model can be used to look for a welfare optimum for any given set of policy instruments. In Table 5, taken from Proost and Van Dender (1998), the effects of different policy options are compared. The first column of this table reports the net economic efficiency effect: this equals the sum of:

- changes in generalised consumer surplus (contains value of changes in time costs) and this for all markets (except labour);
- changes in producer surplus;
- changes in air pollution costs, noise costs and external accident costs;
- changes in tax revenue that received a small premium (7%) to account for the efficiency effects of using the tax revenue to reduce labour taxes.

The efficiency gain obtained with perfect pricing is used as benchmark for the other policy instruments. The three other columns report different effects: change in air pollution damage, total volume of car transport and average speed in the peak period.

Table 5. Global efficiency of alternative transport and environment policy instruments for Brussels in 2005

	Change in economic efficiency (mio EURO/day)	Change in air pollution damage (mio EURO/day)	Total volume of passenger car units	Speed of cars in peak (km/h)
Reference	0		100	23
Perfect marginal social cost pricing	100% (= +0.703)	-0.015	78	40
Cordon pricing	+52%	-0.001	89	33
Parking charges	+32%	-0.005	95	26
Emission standard (consumer paid)	-0 %	-0.006	100	23
Emission standard (government paid)	-0%	-0.006	100	23
fuel efficiency standard (consumer paid)	-17%	-0.016	98	24
fuel efficiency policy (via fuel tax)	+5%	-0.016	95	26

Perfect pricing of external costs leads to lower air pollution damage mainly as side effect of lower volume of car use. The lower value of car use is the result of different effects that are mainly targeted at reducing congestion: more car pooling, switch to other modes and a smaller number of trips. This table illustrates that the welfare maximising policies for the transport sector are those policies that address as directly as possible the problem of congestion and unpaid parking. The air pollution benefits of this policy (-0.015) are only 2% of the total efficiency gains that are achieved in this scenario. These benefits are the result of smaller volumes (passenger km decreases by 22%, carkilometre by more than 30%) and of a smaller share of diesel cars.

Congestion problems can be tackled by cordon pricing (toll levied on commuters at entrance of city, the toll is differentiated between peak and off peak) or by parking charges. In the parking charges policy, all drivers are forced to pay for their parking costs (at destination), moreover the parking charges contain a special tax to discourage the overall level of car use. Both policy instruments generate important efficiency gains. The size of the efficiency improvement is strongly correlated to the increase in speed they can generate in the peak period.

The emission standard scenario assumes that one can get cars with lower emissions of conventional pollutants at an investment cost per vehicle that varies between 225 and 824 EURO per car. These are data taken from the AOP-I results. The efficiency benefits vary slightly in function of whether the consumer or the government pays for the cleaner cars. There is a difference because government funds have a marginal cost higher than one (in fact 1.07) and because there is an income effect for the consumer that affects demand for transport. Such emission standards can give rise to important reductions in the emission of conventional pollutants but the total efficiency gain is smaller and even negative. The explanation lies in the high marginal abatement cost that is not compensated by air pollution benefits.

The fuel efficiency standard scenario corresponds to the introduction of the 5 litre car in 2005. The second fuel efficiency scenario means that the use of a 5 litre car is stimulated via higher fuel taxes rather than through a standard imposed by government. Both scenarios generate approximately the same gain in air pollution benefits. These air pollution benefits consist mainly in the reduction in diesel fuel and in the lower emissions of PM₁₀. The fuel efficiency standard is a less interesting policy than the fuel tax policy because in the former there is almost no effect on the volume of transport and on congestion.

Not everybody shares the view that fuel efficiency standards are a very costly option to reduce CO₂ emissions. In the EU, the major policy decision on CO₂ emissions is the voluntary agreement on fuel efficiency standards that is concluded with the association of automobile manufacturers. The proponents of fuel efficiency standards point to the benefits for myopic consumers⁹ that are not aware of the fuel costs and to the large technological potential. The major flaw in their argumentation is that the present high excises on gasoline and diesel fuel make that the marginal cost of making more fuel efficient cars is indeed low for consumers. They use consumer prices to estimate the benefit of one litre of fuel saved. From a society point of view prices before tax have to be used to compute the real benefits of more fuel efficient cars and this reduces these benefits to one third or less.

⁹ Koopman (1995) using the EURCARS model of the European Commission finds that a CAFE standard is only slightly more costly than a CO₂ tax for the same 10% reduction in CO₂ emissions in the transport sector. His result can be explained by the very high implicit discount rate (up to 50%) he attributes to car buyers. There is no clear empirical evidence for such a high rate. Other studies of the car market (Verboven, 1997) point to a more normal 10%.

Table 5 is an illustration for one urban area in Europe. Part of the analysis has been redone for other areas. The major conclusions are that off-peak road traffic tends to be taxed too much and that peak road transport in urban areas is underpriced [De Borger & Proost, (2000)].

Table 5 is useful to illustrate the relative importance of different types of *ancillary benefits* and their impact on the policy selection process. The most important external cost and potential ancillary benefit is probably congestion in urban areas. The traditional instruments for GHG reduction in the transport sector (fuel efficiency policies and fuel tax policies) are not very cost-effective and generate almost no ancillary benefits. The reasons are that the fuel price instrument has already been used too much and is not time and place specific and that the existing air pollution regulation is starting to put very clean (conventional pollutants) on the market. New instruments (road pricing, parking charges) that affect the congestion problems in a more direct way can generate important overall efficiency gains and reduce the emission of GHG as a by product. These policies could be considered as GHG policies with very high ancillary benefits.

4.2 USA

In the USA, fuel efficiency policies have been used in the past and it looks as if they are the major instrument considered to save GHG emissions in the transport sector. Bernow and Duckworth (1998) count on mainly fuel efficiency policies to stabilise GHG emissions in the transport sector between 1990 and 2010. For cars they count on a fuel efficiency improvement of 1mpg per year, reducing the average consumption from 25 mpg (9.4 l/100km) to 45 mpg (5.2 l/100km) in 2010. After 2010, one counts on new fuels and new vehicles to improve the fuel efficiency.

Originally, fuel efficiency policies have been introduced to reduce oil import dependency and not air pollution emissions. The CAFE (Corporate Average Fuel Efficiency) policy has been studied extensively. Green and Duleep (1993) and Greene (1998) show that the CAFE regulation succeeded in bringing down the fuel consumption by cars at a low cost. The major benefits are fuel savings (if oil prices continue to increase and if discount rate is low) and oil market effects (the international oil price decreases and the security of supply improves through a leftward shift of the demand curve). The major cost is the increase in manufacturing costs of cars¹⁰.

Ancillary benefits (or costs) of this type of GHG reduction policies (beyond the oil market effects) are the effects on the emissions of other air pollutants and effects on traffic safety. The effects on congestion will be small as the overall car use was almost not affected. CAFE standards on cars could have deteriorated the urban air quality by increasing the life of older vehicles and by a shift to unregulated light trucks. According to Green (1998), these effects exist but are not that important. CAFE standards reduce fuel consumption and indirectly also the emissions of other pollutants. Harrington (1997) has shown that, although for new cars there is no relationship between tailpipe emissions and fuel consumption, there is a close positive correlation between fuel consumption and VOC and HC emissions for older cars.

¹⁰ Knowing the cost of emission regulation of cars is far from obvious [see Bresnahan, Yao (1985) and MCCConnell *et al.* (1995)].

There are two ways a CAFE standard can affect traffic safety. It can affect the overall volume of car use and it can affect the type of car that is build. The overall car use was almost not affected. When more fuel efficient cars means lower vehicle weight, the fatality rate of car accidents can increase. Khazzoom (1994,1996) found no statistical relationship between vehicle weight and highway fatalities. If weight reductions are achieved via a switch to lighter material rather than through downsizing, there may not be any significant effect on fatalities. This debate is not closed as the fatality rate may also depend on the composition of the vehicle stock. The increased use of light trucks (that escape the CAFE regulations) may increase fatality rates for cars. In conclusion, air pollution reduction may be an ancillary benefit, negative effects on fatalities are probably small so that there is no compensating increase in ancillary costs. Finally the effects to be expected from suppressed traffic are small too.

Greene has studied the past performance of CAFE policies. It is not obvious that stronger CAFE standards are the best instrument to reduce GHG emissions in the future. Dowlatabadi, Lave and Russell (1996) conclude that CAFE regulations do indeed reduce GHG emissions but they are not a free lunch as they remain costly and do not necessarily reduce the urban ozone concentrations. They think that there may be cheaper ways to reduce CO₂ emissions than through fuel efficiency regulations in the transport sector.

The study of external costs of transport, the basic ingredient for estimating ancillary benefits has recently received more attention (see Greene, Jones, Delucchi,(1997)). Other transport and environment policies that have received attention in the last years are subsidies to alternative fuel vehicles (Kazimi, (1997)), accelerated scrapping schemes (Alberini *et al.* (1996) and pay at the pump insurance schemes (Kavalec and Woods, (1999)).

4.3 *Developing Countries*

There exist almost no systematic discussions of the economics of transport and environment in developing countries and GHG emission reduction in the transport sector¹¹. It may be useful to line up differences and parallels with the OECD countries.

The policy discussion in developing countries will be different on three points.

First cars used in developing countries will not be as clean as in Europe or the USA: there exist many old vehicles and the technology used in new vehicles is not always the most recent one. This means that conventional air pollution emissions can be 5 to 10 times as high as in OECD countries and that reduction of conventional emissions can be an important source of ancillary benefits.

Second, although the same fuel tax and compulsory insurance policies can be used as in OECD countries, the monitoring and the enforcement of these policies are much weaker. For this reason, accident costs will be internalised to a smaller degree and savings in external accident costs can be an important source of ancillary benefits.

¹¹ Except for work by the World Bank on CO₂ and transport [see Schipper and Marie-Lilliu (1999)] and work on air pollution damages presented at this symposium.

Third, transport needs and urbanisation are growing at a much higher pace in developing countries than in the OECD countries. This means that road expansion decisions, mass transit investments and land use are crucial and interdependent policy decisions. There are opportunities to realise efficiency gains and to reduce the volume of road traffic and emissions by integrating better road pricing policies and better mass transit policies. Land use policies are very important too but the contribution of economic knowledge is limited to a list of “errors not to make” rather than a full understanding of the optimal policy.

5. Conclusions

The road transport sector is characterised by many important external costs so there is a potential for ancillary benefits of GHG reduction policies in this sector. The relative importance of the different externalities and their impact on the ranking of policies will be different.

In OECD countries there exist strong emission regulations and an enforced system of accidents insurance and liability rules. This explains why the most important external costs are congestion and to a much smaller extent accidents and air pollution. The traditional GHG reduction policies (high fuel taxes in the EU and strong fuel efficiency policies in the USA) have already been used intensively in the past. They are not very cost-effective and there are no important ancillary benefits to be expected from them. More interesting instruments are time and place differentiated pricing of transport that address congestion externalities directly and could generate a reduction of GHG emissions as by product. These policies need to be tailored to the local transport needs and require an integrated assessment area by area. The methodology for these studies exists but applications are still scarce.

In developing countries there are strongly growing transport needs and poorly enforced emission regulation, accident insurance and liability systems. Strongly growing transport needs imply that road expansion decisions, mass transit investments and land use planning are the major instruments. Poorly enforced accident insurance and emission regulations imply that external accident costs and external air pollution costs can be an important source of ancillary benefits. In order to use the same type of integrated assessment tools as in the OECD, these tools need to be extended to include better the land use policies and infrastructure extension. This remains an intellectual challenge.

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