UNITED NATIONS

E

Economic and Social Council

Distr.
GENERAL

TRANS/WP.5/2002/3/Add.4
19 June 2002

ENGLISH ONLY

ECONOMIC COMMISSION FOR EUROPE

INLAND TRANSPORT COMMITTEE

Working Party on Transport Trends and Economics
(Fifteenth session, 2- 4 September 2002,
agenda item 9)

RELATIONSHIP BETWEEN TRANSPORT AND ECONOMIC DEVELOPMENT

Addendum 4

The External Costs of Transportation

Summary Report

Transmitted by the Government of Belgium

Sustainable Mobility Programme
Federal Office for Scientific, Technical and Cultural Affairs,
State of Belgium, Prime Minister's Services

The External Costs of Transportation

Summary Report

January 2001

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1. INTRODUCTION

When consumers and producers decide whether to make a trip, by which mode and at what time, they evaluate the available alternatives on the basis of the costs and benefits of an extra trip for themselves. These are the so-called marginal private costs and benefits. The term “marginal” refers to the change in total costs and benefits due to an extra trip. The marginal private costs include the resource costs (for example, the fuel costs, the vehicle costs and the insurance premium), the taxes, the own time costs and the costs associated with the exposure to the accident risk. However, each trip also causes costs for the other transport users and for society in general. The additional transport users only partly take into account these costs in their decision process, via the taxes and the insurance premia they pay. The costs that are not taken into account are called the marginal external costs. Because of these, the traffic flow resulting from the decisions of the households and firms is larger than what is socially optimal. Moreover, the spread of trips over time is not optimal: too many trips take place in the peak period. The share of the various transport modes and the type of vehicles used is also sub-optimal.

Policy makers can use various instruments to remedy this situation. Three categories of instruments can be distinguished: economic instruments, command-and-control measures and changes in the infrastructure. Information about the level and structure of the marginal external costs is a crucial input in the design of these policies.

The project calculates the marginal external costs of transport use in Belgium. This summary report discusses the findings for three main categories of external costs: environmental costs, accidents and congestion costs. Road damage externalities, which are caused mainly by trucks, are not considered here - with the exception of the air pollution costs related to road maintenance. The environmental costs were analysed by the VITO team, the CES - K.U. Leuven team was responsible for the accident costs and the UFSIA team studied the congestion costs.

The environmental costs

The marginal environmental costs probably are the best understood category of external costs. The project has led to a detailed and transparent set of estimates for Belgium. The study covers all major current and future (up to 2005) transportation modes, fuels and technologies for passenger and freight transport. It is based on a detailed inventory of emissions following the state of the art in life cycle analysis and emission models of transport activities. The analysis includes emissions related to the use phase of the transportation means, those related to the supply of transportation fuels and the construction of vehicles and, finally, those related to the maintenance of infrastructure.

The environmental damages from these emissions are assessed in a detailed bottom up assessment following the damage function approach of the European ExternE method. These damages mainly cover air pollution impacts on human health, crops, materials and global warming effects. Ecological impacts and human health impacts from noise are not yet included in the analysis given the large uncertainties that are still surrounding these impacts and their monetary valuation.

The accident costs

The analysis of the marginal external accident costs still raises many conceptual difficulties. The research consists of two parts. The first part aims to give a thorough theoretical background for determining these costs. In a first step this is done with the help of a simple theoretical model which makes abstraction of the impact of liability rules and insurance on the road users' behaviour. In a second step the role of liability rules and insurance is considered explicitly.

The second part aims to determine the monetary value of one of the most important components of the accident costs, namely the health impacts. Surveys were conducted in Flanders in order to derive the value of a statistical life/injury. Three survey methods are used: contingent valuation, a combination of contingent valuation and standard gamble, and a choice experiment. The data will be used to compare these three methods in terms of their performance in producing a reliable monetary valuation of a statistical life. The results of this exercise should contribute to the current discussion in the literature about the best survey technique to use in this field.

The congestion costs

The congestion costs are another category of costs for which conceptual difficulties still exist. For this category there is also a large gap between the scientific basis and the acceptance by the policy makers. The project has extended the existing methodology to take into account three aspects: the dynamic adjustment of departure times, the treatment of uncertainty and the provision of information to the transport users.

The next three sections of this report briefly discuss the project's results for the three external cost categories. Section 5 concludes and presents directions for future research.

2. THE MARGINAL EXTERNAL ENVIRONMENTAL COSTS

L. Int Panis, Leo De Nocker (VITO)

2.1. Introduction and scope

People who drive their car to a nearby city, have probably thought about how much time it would take them and what it would cost. But most people don't take into account the impacts of their trip on public health, the historical buildings in the city centre or on forests a 1000 km downwind. Damages to man and the environment caused by polluting emissions are called environmental external costs.

This report focuses on the evaluation of air pollution impacts since these are believed to include the most important pathways. The evaluation is based on the accounting framework of the European ExternE project. Earlier estimates for Belgium using ExternE data were based on extrapolation of case studies for neighbouring countries or out of date methodologies. The results of this project are more detailed, accurate and up-to-date and provide the basic data for analysing a myriad of questions related to transport and environmental policies.

The study covers all major current and future (up to 2005) transportation modes (road, railway

0and waterway), fuels and technologies for both passenger and goods transport. A wide range of proven air pollution impacts on public health, crops and materials are calculated. In addition we also look at global warming impacts. The major missing categories are ecological impacts and public health impacts from noise.

The analysis covers the use phase of these technologies in detail, and also looks in a more general way to the impacts of the full life cycle (LCA analysis) of the provision of fuels, vehicles and infrastructure. The main focus of the study is on the analysis and comparison of the use phase of current and future technologies for road transport, and on the full life cycle analysis and comparison for different transportation modes. Results were also aggregated at a national level for all road transport modes and trends over time are evaluated.

2.2. Results and discussion

Three main conclusions are immediately clear from the results:

- Environmental damage costs can be significant
- Environmental external costs are site specific
- Environmental external costs depend on the type of technology and fuel.

Although we were successful in quantifying external costs of air pollution on public health, crops and materials, we could not monetize impacts on ecosystems. This is especially important for impacts of NOx from the use-phase, and from a wide variety of emissions from the other phases. We did not include estimates of noise (although some are available in literature) and the damage estimates for global warming are far from complete. The data given below are thus a lower bound of the estimate of total environmental damages. Nevertheless, these damage costs are significant, but uncertainties have to be taken into account.

In contrast with emissions from high stacks, tailpipe emissions from cars occur close to the ground. The highest concentrations can therefore be found close to the road. Hence the exposure to primary pollutants depends on the population density in the vicinity of the road. In the latest methodology this has been taken into account through a detailed GI5-analysis. If more people are exposed or at-risk, more people will suffer the consequences of the pollution which are evaluated with epidemiological techniques. Therefore, we find much higher externalities for transport in cities than in rural areas. This effect is amplified by the fact that most vehicles drive at a lower speed (with higher resulting emissions per km) in cities.

In addition to location, the two most important factors are the relevant European emission standards (or Euro types) and fuel type. Summarizing the effect of these factors for passenger cars we find that: on all trajectories, old diesel vehicles (uncontrolled) have the highest external costs by far. Costs are often 2 or 3 times higher than those of uncontrolled petrol fuelled cars. Progress has been made in limiting the externalities of diesel vehicles with the introduction of the Euro 1 and Euro2 emission standards, but only the very latest models (complying with Euro3 standards) seem to perform better than uncontrolled petrol cars.

Logically in each category the later Euro-types perform better than the older ones. The largest decrease in external costs was achieved by the introduction of the Euro 1 standard for petrol cars, which brought a decrease with a factor of 3 from Euro0 externalities. Subsequent improvements from Euro2 and Euro3 legislation are substantial but relatively lower.

Results for LPG cars with a three-way catalytic converter are about 50% lower than for petrol cars on the same trajectory. Older LPG fuelled vehicles without a catalytic converter are no match for today's petrol cars and, in rural conditions, may even have higher externalities than the latest diesel models.

For trucks we find that larger trucks have higher externalities per kilometre, but they perform better (environmentally) than smaller trucks in terms of costs/ton km.

In a next step, marginal externalities from all vehicles in the fleet were added into a total (aggregated) external cost (Table 1). Despite impressive technological improvements, the introduction of new vehicles during the last decade has not led to an appreciable decrease in total emissions or environmental externalities.

The numbers from Table 1 are hardly lower than the annual total that was derived for the years 1993-1997. If any improvement could be found over that period, it could be completely attributed to passenger cars. This result can be explained by the combination of: growing fleets of all road vehicles, an increased specific mileage for most vehicles and shifts within the fleets' composition. The two most important evolutions in fleet composition are the shift from petrol to diesel passenger cars and the shift to larger trucks in goods transport.

There are two main possibilities to decrease the air pollution from transport, either continue the technological improvement and introduce new fuels and new technologies or shift the growing demand for passenger and goods transport to other transport modes. Both were studied in this report.

Table 1: Total external costs for the use and non-use phase for different segments of the fleet (in billion Euro) for Belgium, 1998

External costs	Billion Euro				
	Passenger cars	Heavy Duty Trucks	Bus & Coach	Total (all categories)	%
Use phase	1.59	0.64	0.17	2.4	66%
Non-use phase					
fuel production	0.15	0.04	0.00	0.19	*5%*
vehicle production	0.37	0.13	0.01	0.52	*14%*
infrastructure	0.41	0.11	0.01	0.53	*15%*
Total (use + non-use)	2.52	0.92	0.19	3.6	*100%*
%	69%	*25%*	*5%*	*100%*	

Emerging vehicle technologies could have several important effects:

- If diesels are equipped with PM filters that can reduce their emission to the level of petrol cars, they can no longer be considered more polluting.
- LPG, CNG and Hybrid vehicles achieve somewhat lower externalities than modern petrol cars. Besides the presumably lower PM emissions they also have lower greenhouse impacts.
- Hybrid vehicles have the lowest externalities on all trajectories. Unfortunately, we have no detailed information for the Life Cycle costs (including the battery) which will determine if hybrids are really an environmental success.
- Biofuels have the advantage of being CO_2 neutral but there is no information on the combination of these fuels with sophisticated engines and after-treatment, whereas case studies also show potentially significant impacts from the upstream life cycle of the biofuels.

Life Cycle costs and occupation rates are very important in the comparison of private and public passenger transport. Diesels (trains, buses and cars) perform much worse than electric vehicles (trains, trams and trolleybus) in the use-phase. Including LCA costs, all forms of public transport have advantages over cars (if occupation is high enough) with the possible exception of diesel buses and trains in large urban areas.

For goods transport, we find that even the most advanced diesel trucks have higher external costs (incl. Life Cycle costs) than any of the other modes. Diesel trains have higher use-phase externalities from air pollution, but lower Life Cycle costs. Inland ships have the lowest use-phase costs. Their Life Cycle costs are lower than for trucks, but higher than for trains. All things combined (including noise) this leads to the conclusion that (large) inland ships seem a good alternative to road or rail transport from an environmental point of view.

3.1. The theoretical analysis

First, a simple theoretical model was developed to analyse the marginal external accident costs in a framework that does not consider explicitly the impact liability rules and insurance on the behaviour of the agents. The model includes both the monetary and the non-monetary costs of accidents. It assumes that the individual chooses his consumption bundle such as to maximise his expected utility subject to a number of budget constraints. The expected utility is a function of many factors, one of which is the accident risk. The accident risk and the material damage that occurs if an accident takes place, depend on exogenous factors and on factors controlled by the individual (the number of kilometres he drives and the safety measures he takes, for example, the installation of an air bag, his driving behaviour).

When the individual decides how much he drives and which safety measures he takes, he only takes into account his own costs and benefits. However, the decisions of the consumer also have an impact on the other road users. One can distinguish the following effects:

- the welfare cost associated with the change in the accident risk of the other road users - should this change take place

- the net costs of defensive behaviour of the other road users: this effect is present if a change in the traffic flow or the level of care of a road user has an impact on the consumption of transport and safety measures by the other road users (a typical example is a cyclist who switches to car use because of an increase in the accident risks for cyclists).
- the impact on the material damage of the other road users (taking into account their defensive behaviour)

The additional road user also causes costs to society. These include medical costs, police costs, the net-output loss and possibly the reduction of labour productivity. Whether this category should also include a value for the pain, grief and suffering of relatives and friends depends on the form of altruism which occurs. This is discussed by Jones-Lee (1989).[1] If altruism means that one is concerned only for the safety of other people, then one should include a value for the pain, grief and suffering of relatives and friends. However, if altruism means that one is concerned for the general welfare of others (which depends not only on their safety, but also on other factors), then it should not be included in order to avoid double counting.

The simple theoretical model does not explicitly take into account the impact of liability rules and insurance on the behaviour of the road users. An overview was made of the literature dealing with these issues. It aims to answer the following questions: Are well designed liability rules - in combination with regulation or not - sufficient to reach the socially optimal level of accident costs? Or is it necessary to complement them with other instruments, such as economic instruments (Pigouvian taxes or subsidies) or insurance regulation? These issues are analysed in the framework of so-called victim-aggressor models, which make a distinction between two parties, namely the injurers and the victims, with the victims alone experiencing the accident loss. This framework is of relevance, for example, for accidents between motorized and non-motorized transport modes.

In order to focus on the role of liability rules in reducing accident losses, the analysis first assumes that the agents are risk neutral. Next, the case of risk-averse individuals is considered. This implies that the social optimum involves not only the reduction of accident losses but also the protection of risk averse parties against risk. Risk averse agents will purchase insurance coverage. The paper considers whether this has implications for the incentives associated with liability. Moreover, the problem is complicated by the existence of the moral hazard problem. This arises if the insurer cannot observe the behaviour of the insured and therefore cannot adjust the insurance premium in function of this behaviour.

3.2. The monetary valuation of the health effects of accidents

An important input in the calculation of the marginal external accident costs for Belgium is the monetary valuation of the health impacts of accidents. This includes not only the pure economic costs (medical costs, income losses etc.) but also a measure of the loss of enjoyment of life in the case of an injury or fatality. The first category of costs can be valued relatively easily. The second category is more difficult to value.

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[1] Jones-Lee. M.W., 1989, The economics of safety and physical risk, Basil Blackwell, Oxford.

The project uses surveys of the Flemish population to determine the value of a statistical life or injury. This is defined as the monetary value of the avoidance of one death or injury, irrespective of who is saved. The project uses so-called stated preference methods, which ask the respondents in a more or less direct way how much they are willingness to pay for a hypothetical change in accident risks. Various SP methods exist. After a survey of the literature, it was concluded that there is not yet a consensus on which is the best method. Therefore, it was decided to compare three methods on the basis of three small (288 respondents per questionnaire) surveys. The three methods are: the contingent valuation method (CV), a combination of CV and standard gamble (CV+SG) and a choice experiment (CE).

In the CV questionnaire the respondents are asked to express their willingness-to-pay for a reduction in the risk of fatal and/or non-fatal traffic accidents. The questionnaire is based on Jones-Lee et al. (1985), Beanie et al. (1998) and Jones-Lee et al. (1998)[2] Three variants of the questionnaire were made in order to test for problems such as the embedding, scope and sequencing effects, which were identified in previous CV studies. These problems are related to the fact that the accident risks in transport are very small.

The CV+SG questionnaire is based on Carthy et al. (1999)[3]~. It proceeds in two steps. Step 1 uses the CV method to determine the WTP for a complete recovery from a non-fatal light injury. The respondents are also asked for their willingness-to-accept for the same injury. Step 2 uses the standard gamble method. The respondent is told that he has been involved in a traffic accident and will die if he is not treated. He is asked to make a choice between two treatments, which have a different risk of failure (resulting in death) and different outcomes when successful. Carthy et al. indicate that the CV+SG questionnaire is understood better by the respondents and that it is plagued less by the problems of the CV method. However, they also point out the possibility of consistency problems. Therefore, we used two versions of the questionnaire in order to test for these problems.

Finally, the CE questionnaire asks the respondents to make repeated choices between two roads that differ in terms of three characteristics: travel time, number of fatal accidents and the price of a trip. The questionnaire is based on Rizzi et al. (1999).[4] The method is relatively new in the

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[2] Beanie, J. et al., 1998, On the contingent valuation of safety and the safety of contingent valuation: Part 1 - Caveat investigator, Journal of Risk and Uncertainty, 5-25.
Jones-Lee, M. et al., 1985, The value of safety: Results of a national sample survey, The Economic Journal 95, 49-72.
Jones-Lee, M. et al., 1998, Questionnaire used for New Zealand value of transport safety study, University of Newcastle upon Tyne.

[3] Carthy, T. et al., 1999, On the contingent valuation of safety and the safety of contingent valuation: Part 2 - The CV/SG “chained” approach, Journal of Risk and Uncertainty 17, 187-213.

[4] Rizzi, L.I.. and J. de Dios Ortuzar, 1999, Sesgo De Presentacion y Efecto Marco En Ecuestas De Preferencias Declaradas. Una Aplicacion Al Caso De La Seguridad Vial an Carreteras, Pontificia Universidad Catolica de Chile, Departamento de Ingenieria de Transporte.

domain of transport safety valuation. This project will test whether it is suited for the monetary valuation of accidents.

The surveys were carried out in August-September 2000. At this moment the analysis of the survey data has not yet been completed. The work will be continued in the future. The aim is to compare the three survey techniques and to asses their strengths and weaknesses.

4. THE MARGINAL EXTERNAL CONGESTION COSTS

B. De Borger (UFSIA)

4.1. Purpose of the project

There exists a broad consensus on the detrimental effects of increasing external transport costs (congestion, pollution, noise, accidents) for the elaboration of a durable transport policy. The control of transport externalities is therefore an important ingredient of an economically sensible policy agenda. A large number of specific policy measures have been proposed, including infrastructure investments, pricing policies, direct intervention, traffic management techniques, etc. The purpose of this project is to study external congestion costs, an important component of total external costs, taking into account recent insights developed in the economics literature.

4.2. Contribution of the project

The standard approach for the determination of the external congestion costs in economic policy models assumes a static framework and a very simplified spatial environment. It consists of determining, for a given trajectory, the empirical relationship between the traffic flow and the average speed of that flow. This is based on the idea that an increase in traffic flow influences average speed and, therefore, the time needed to make a certain trip. Time losses due to congestion are valued negatively by the travellers. The marginal external congestion cost is then defined simply as the total value of the time losses for the other road users due to an additional vehicle. The calculation of the marginal external congestion costs requires an estimate of the impact of an additional vehicle on the average speed of a traffic flow and the valuation of the time losses.

This project aims to give a better estimate of the marginal external congestion costs by taking into account a number of complications which were ignored up to now in the existing studies for Belgium. The first extension is the introduction of dynamics. This refers to the dynamic adjustment of departure times (and therefore the time of travel) which is caused explicitly by congestion. Indeed one observes in reality that congestion induces people to adapt their travel behaviour (leaving earlier or later, choosing another mode or route, etc.). The consequences of these endogenous adjustments were not considered in previous models for Belgium. Recent theoretical work [Arnott et al. (1993), Noland and Small (1995), Noland (1997)[5]] allows to incorporate this phenomenon and to determine its impact on congestion and external costs. The second extension is related to uncertainty. It is important to consider non-recurrent and structural or recurrent congestion simultaneously. Traffic jams are not only a structural phenomenon (recurrent congestion: demand exceeds capacity), but also partly dependent on stochastic and non-perfectly predictable elements (weather conditions, accidents...). People take into account the probability of unexpected circumstances in function of the available information. However, the variability of the unpredictable circumstances plays an important role in the behaviour of the commuters and in the determination of the observed level of congestion. A third extension concerns the possibility to reduce the uncertainty about congestion by giving specific information to the travellers. Which information has a positive impact? Is the provision of information always welfare improving?

4.3. Intuition of the model

To describe the intuition underlying the approach followed in the project we consider a specific example. Suppose that a group of N commuters has to travel on a certain trajectory by car. Each commuter has a desired arrival time at the end of the trajectory. Because of differences in the time at which work starts, differences in preferences, and variability in the distance to be travelled after the trajectory these desired arrival times can vary strongly between commuters. Each commuter determines his ‘optimal’ departure time in function of the desired arrival time taking into account two types of congestion. On the one hand there is recurrent congestion: the traffic flow on the trajectory determines the average speed. On the other hand there is also a probability of unexpected additional congestion; the time needed to get out of the resulting traffic jam follows a statistical distribution which is assumed to be exponential in this exercise. This reflects amongst other things that the probability of short delays is larger than that of longer incidents. Each commuter is assumed to determine his optimal departure time in order to minimize the total expected cost of the trajectory. He takes into account not only the transport costs, but also the costs of arriving too early or too late. The valuation of these costs can in principle differ between individuals in function of work organisation rules, preferences etc.

In order to infer optimal congestion profiles and to determine the various components of congestion costs, the optimal decisions of all individuals need to be coordinated. Analytically one searches for a Nash equilibrium. To operationalize the model for numerical application, we proceeded as follows. We start from a given distribution of desired arrival times. The period to be analysed is divided into small time intervals. Given the distribution of non-recurrent congestion and therefore a given degree of uncertainty, each individual determines his optimal departure time, conditional upon a given basic congestion pattern. This allows to determine the traffic flow in each interval. This can be used to compute the change in the expected time cost

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[5] Arnott, R., A. De Palma, R. Lindsey (1993), “A structural Model of Peak Period Congestion: A Traffic Bottleneck with Elastic Demand”, *American Economic Review,* 161-179.
Noland, R.B. and K.A. Small *(1995),* “Travel Time Uncertainty, Departure Time Choice and the Cost of Morning Commutes”, *Transportation Research Record,* 1493, 150-158.
Noland, R.B. (1997), “Commuter Responses to Travel Time Uncertainty under Congested Conditions: Expected Costs and the Provision of Information”*, Journal of Urban Economics,* vol. 41, 377-406.

when someone departs slightly later. This leads to a number of adjustments in travel times of individuals. Changes in the congestion profiles then lead again to adjustments in the optimal head times and the traffic flow per interval. Iteration of this procedure continues until a stable congestion pattern is obtained. This can be used to determine various economic measures; of course, we mainly focus on marginal congestion costs.

4.4. Results

Application of the model yields the following general insights.

a. An important part (20%-40%, depending on the circumstances) of the external congestion costs are adjustment costs in travel behaviour. By looking only at the role of travel costs, many previous models have calculated the marginal congestion costs incorrectly. A growing travel demand leads to higher time costs and also to important additional time adjustment costs.

b. The marginal congestion costs depend strongly on the capacity and the desired arrival time. They vary between almost zero in the off-peak period to more than 50 BEF (1.13 Euro) per km in the high peak and with relatively low capacity.

c. An increase in capacity reduces both the recurrent (structural) congestion and the congestion due to unforeseen circumstances. An increase in capacity changes the congestion profile (more clustering around the peak because of higher capacity), leads to a lower global congestion costs and increases the relative importance of the adjustment costs. The impact on the average head start time is small. Higher capacity reduces the spreading of the peak period.

d. A reduction in the uncertainty about non-recurrent congestion leads to a shift in time of the congestion profile. With higher reliability people leave later and cause a peak at a later moment. The share of the scheduling costs diminishes, the share of the costs due to late arrival increases (people leave somewhat later so that costs of arriving too early are reduced and costs of arriving too late increase). The share of transport costs increases when there is less reliability.

e. An important implication is that investments in techniques which reduce the uncertainty about congestion can be much more effective in reducing congestion than direct investments in capacity.

5. CONCLUDING REMARKS

The previous sections show clearly that the research results are the most concrete for the air pollution costs of transport. In the other areas contributions were made to a more correct calculation of the marginal external costs. However, the research in those areas is not yet in a stage that the figures of previous studies can be revised. This difference in progress for the various external cost categories corresponds to a large extent to the state of the art in the literature. While the methodology for air pollution costs is defined relatively clearly, research is still very much in progress for some environmental costs (noise, ecological impacts), for accident costs and for congestion (for example, the dynamic adjustment of departure times, the treatment of uncertainty and the effects of the provision of information).

Nevertheless, the project has enabled the three research teams to further develop their know-how about the marginal external costs. The project has allowed the three teams to be among the top scientific groups active in this area. They play an important role in several European research consortia on the use of external costs of transport (ExternE, UNITE, MC-ICAM). The know-how created in the project will be extremely useful and crucial for the evaluation of policies which aim to reduce the social costs of transport. Interim and draft final results of the project have already been widely spread - both to the scientific world in different related disciplines, and to relevant policy actors. The new insights (e.g. relative importance of health impacts from particles, concept of external congestion costs, ...) have been used for policy-oriented studies and policy preparation.

The project has allowed us to identify several new avenues for future research. In the case of accident costs the role of liability rules and insurance systems in combination with economic instruments deserves further research. On the empirical side, the choice of the correct methodology for valuing a statistical life/injury is not yet fully explored. Also the relationship between accidents and their various determinants (speed limits, variance in speed, traffic rules, etc.) should be explored in greater detail.

For the environmental costs, both a continuous update and further development of methodologies and data is required. The most important areas for improvement are:

- Keeping up to date with technological developments, including both conventional (PM filters, …) and alternative (hybrid vehicles, …) technologies

- Keeping up to date with scientific improvements and reducing uncertainties: the scientific understanding of dispersion, exposure, impacts and their valuation is changing fast, especially in areas related to particulate matter. As this is the major impact category, estimates and uncertainties of external cost data risk to be quickly outdated. Overall, the handling of uncertainty needs to be improved.

- Covering more impact categories and developing new approaches to their valuation: the impacts of noise, impacts on historic buildings, ecosystems and impacts from greenhouse gases. The integration of estimates for different impacts (air pollution, noise, …) based on different assumptions need to be further explored, as is uncertainty analysis.

- A better coverage of all transportation means: improve data for road vehicles other than cars (trucks, motorcycles, ...) and for rail traffic and inland shipping. Especially data related to current and new technologies are lacking, as are data on how to improve their environmental performance.

- Improvement of estimates of the non-use phases: The main areas for improvement include data for projections to 2010, taking into account new and stricter environmental policies, and more realistic data related to fast developing new fuel cycles: the fuel cell, biofuels and electrical vehicles. On the methodological side, the integration of impacts of emissions to water and soil is an important gap in the information.

- New and indirect impacts. Both methodologies and data are lacking to evaluate the relative importance of a number of ‘new’ and indirect impacts. These include impacts of parking and traffic on the ‘quality of life’ in the ‘city’, benefits of walking and cycling on health, impacts of new infrastructure on landscape and biodiversity. Other issues are road dust (related to the discussion on particles), growing interest for some new pollutants (PAHs) or pollutants not well covered (dioxins)

- Uncertainty analysis related to policy applications: To be useful for policy and decision making, the large amount of available data need to be exploited from the perspective of specific policy questions and uncertainty analysis of these answers need to be developed. Also data to evaluate the impact of specific policy measures (e.g., the introduction of particle filters) need to be further developed. For the assessment of local transport policies, integrated models are required that link detailed traffic-air dispersion models with assessment tools.

For the congestion costs additional work is necessary on at least two issues. First, additional research should investigate the underlying determinants of the value of time losses. This was not explicitly studied in this project. Second, the recently developed dynamic models of congestion have to be integrated in welfare economic analysis of pricing and other policy measures to cope with congestion.

The estimation of the total marginal external costs requires a further integration of estimates on congestion, accidents and the environment and public health, and consistency related to their valuation. There is a need for a set of data that can be used to evaluate the cross-links between policies related to environmental protection, safety and congestion. Especially where policies may be in conflict (e.g. lighter vehicles to limit CO_2 emissions versus extra weight of extra safety provisions; higher speeds and therefore lower congestion costs might increase the accident costs), such a set of indicators is required for integrated policy making.

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