Pergamon

Transpn. Res.-A. Vol. 28A, No. 4, pp. 273-287, 1994

0965-8564/94 $6.00 + .00

0956-8564(93)E0010-S

EXTERNAL EFFECTS AND SOCIAL COSTS OF ROAD TRANSPORT

ERIK VERHOEF
Department of Spatial Economics, Free University, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands

Abstract—The article contains a welfare economic analysis of road transport's external effects. First, we discuss the definition of external effects. Applying this definition, it is concluded that road transport activities give rise to a wide range of external costs. However, there are no external benefits associated with individual road transport activities which might compensate for such effects. Therefore, road transport volumes will in general be beyond the optimal levels. Second, we describe a conceptual framework for the analysis of environmental external costs. It is explicitly recognized that not only the externality as such, but also the induced outlays on defensive and abatement activities should play an important role in welfare economic analyses of external effects. Then, this framework is used for the evaluation of the existing empirical work on road transport's environmental external costs (i.e., noise and air pollution). It is concluded that most of the studies carried out in that field will provide an underestimation of road transport's external costs by definition. Finally, some attention is paid to empirical estimates of road transport's accident costs.

1. INTRODUCTION

Along with the growing social pressures resulting from road transport in terms of environmental degradation, noise annoyance, and accidents,[1] a large body of literature on road transport's external effects has emerged over the last two decades. However, due to differences in the interpretation of the concept of externalities and the wide range of techniques and methodologies employed in the estimation such effects, empirical estimates of road transport's external costs may differ by a factor of 10 or more—whereas they often intend to measure the same thing. At a more fundamental level, there is even no consensus on the question of whether external benefits of road transport might compensate for the external costs. Therefore, the following issues are addressed to in this survey on economic analyses of road transport's external effects.

Section 2 is dedicated to the definition of *externalities*. Applying this definition in Section 3, it is concluded that road transport hardly yields any positive external effects, however, considerable negative externalities are involved. These are addressed to in the remaining sections. In Section 4, some conceptual issues in the analysis of external costs of road transport are discussed. In particular, *environmental* externalities are in the centre of interest. A conceptual framework is presented in which it is explicitly recognized that not only the externality as such but also induced outlays on defensive and abatement technologies are relevant in welfare economic analyses of external effects. Apart from having theoretical implications, the framework can be used for the evaluation of the existing empirical work in the field. This is the subject of Section 5 and finally, Section 6 will discuss our main conclusions.

2. A DEFINITION OF EXTERNALITIES

Although the concept of external effects is widely used in economics, there is no consensus on its exact definition and interpretation. However, it is commonly recognized that externalities are an important source of market failure. Their existence leads to a

The author is affiliated to the Tinbergen Institute and participates in the VSB-fonds sponsored research project "Transport and Environment."

[1]Comparable effects caused by other land transport modes are often much smaller, both in an absolute and in a relative (per person- or ton-kilometre) sense.

deviation from the neoclassical world in which the price mechanism takes care of socially optimal resource allocation (*Pareto efficiency*). Himanen, Nijkamp, and Padjen (1993) suggest to use the term *signal failure* to describe this kind of market failure: market prices no longer reflect social costs (or benefits) and additional taxes (or subsidies) are called for to restore the efficient workings of the market mechanism. Furthermore, it is generally accepted that the source of externalities is typically to be found in the "absence of property rights" (Baumol & Oates, 1988, p. 26). Hence, the theory of externalities is often applied in environmental economics. Environmental quality is a typical "good" for which property rights are not defined and equivalently no market exists.

These commonplaces may clearly indicate the causes and consequences of external effects but still leave the definition unclear. However, an exact definition is necessary to identify road transport's external effects. It should make an unambiguous distinction between external effects and any other form of *external relations* (e.g., market transactions, charity, criminality, etc.), which have different characteristics, different consequences, and therefore require different approaches—both in a theoretical respect and in the practice of government intervention. The following definition relies on those given by Mishan (1971, p. 2) and Baumol and Oates (1988, p. 17):

> An external effect exists when an actor's (the receptor's) utility (or profit) function contains a real variable whose actual value depends on the behaviour of another actor (the supplier), who does not take these effects of his behaviour into account in his decision making process.

Two specific points deserve some closer attention: First, by focusing on real variables (i.e., excluding monetary variables), ordinary economic dependencies such as so-called *pecuniary externalities* are ruled out. Such relations do not lead to shifts in production and utility functions but merely to movements along these functions. Consequently, no intervention is required in order to secure Pareto efficiency (Fig. 1). Second, the condition

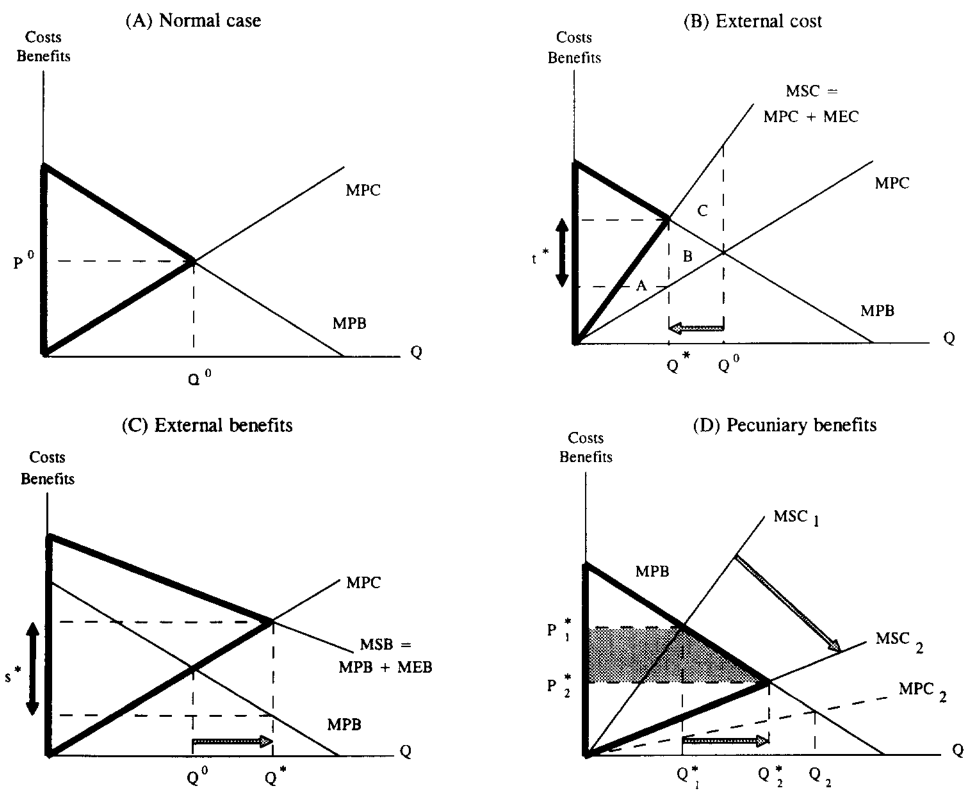

Fig. 1. Policy implications of external costs, external benefits, and pecuniary benefits.

concerning the supplier not taking the externality into account in his/her decision-making process distinguishes externalities from other types of unpriced external relations which may occur for various reasons. For instance, *barter trade* does of course not involve any external benefits. Furthermore, the supplier's utility function may include the receptor's utility level as determining variable. However, *criminal (violent) activities* do not qualify as external costs. Reversely, *altruism* or *goodwill activities* do not qualify as external benefits. According to Mishan (1971): " . . the essential feature of an external effect (is) that the effect produced is not a deliberate creation but an *unintended* or *incidental* by-product of some otherwise legitimate activity" (p. 2). Whereas external effects will lead to an inefficient outcome in the Pareto sense, this does not in general hold for the situations just mentioned. Most obvious are the occurrence of pecuniary benefits and barter trade. In such cases, individual welfare maximizing behaviour can be expected to be perfectly in line with Pareto optimality. Situations where individual utility functions contain others' utility levels will often involve *equity* rather than *efficiency* matters. Government policies concerning such situations, such as free public promotion for charity funds (or against hooliganism) will therefore be based on social rather than efficiency considerations.

Consequently, the question of whether unpriced external relations are either external effects or other types of unpriced external relations involves important policy consequences. This is demonstrated in Fig. 1 for a certain activity Q. The standard case in Fig. 1A shows the optimal workings of the market mechanism in absence of external effects. In this case, no government intervention is called for: Adam Smith's invisible hand secures social welfare maximization (the bold triangle) at the market equilibrium Q_0 where marginal private cost (MPC) equals marginal private benefits (MPB). MPB and MPC can be interpreted as the benefits and costs as experienced by one actor. They can also be thought of as being the demand and supply curves for a marketed good, in which case P_0 is the market clearing (efficient) price.

The existence of (marginal) *external costs* (MEC) (see Fig. 1B) drives a wedge between marginal social cost (MSC) and marginal private cost. The market outcome Q_0, where *private* welfare is maximized is not optimal from a social point of view. The resulting level of the externality (A + B + C) is excessively large. *Social* welfare maximization requires the activity to be restricted to a level of Q^*, where the marginal social cost is equal to the marginal benefits and the dead-weight welfare loss C is avoided. This optimum can for instance be accomplished by means of a *quantitative restriction* (Q^*) or a *Pigouvian tax* (t^*) on the activity. The triangle A gives the optimal level of the external cost. The bold triangle again represents maximum social welfare.

Figure 1C shows the reverse case, where (marginal) *external benefits* (MEB) exist. Marginal social benefits (MSB) now exceed the marginal private benefits. The policy implications of external benefits are contrary to those of external costs. Here, social welfare maximization requires encouragement of the activity up to Q^*, for instance by means of Pigouvian subsidization (s*).

Finally, Figure 1D illustrates the case of *pecuniary benefits*. We take Fig. 1B as a starting point, assuming that the activity gives rise to external costs. Then, suppose the private cost curve of the activity shifts downward, perhaps due to technological developments or lower input prices. Assuming unaltered external costs, MSC will fall as well. A new social optimum Q_2^*, with a higher social welfare arises: the bold triangle is increased in comparison with Fig. 1(B). Moreover, if Q is a traded good and MPB reflects market demand, the *consumer surplus* increases by the shaded area. This results from the lower market price P_2^* and the larger quantity sold Q_2^*. This benefit, however, is not external but pecuniary: it results from a movement along—not a shift in—the MPB curve. For the attainment of the new social optimum (the move from Q_1^* to Q_2^*), market forces can be relied upon and there is no reason for stimulating the activity unlike the case of external benefits. Also, the pecuniary benefits do not "compensate" for the external costs: social welfare maximization still requires a restriction from the new market outcome Q_2 to the new social optimum Q_2^*.

Consequently, the question of whether unpriced costs and benefits of road transport are either external or pecuniary in nature, is crucial from a policy point of view. The next section therefore discusses the important question of whether road transport gives rise to external costs and/or benefits.

3. EXTERNAL EFFECTS OF ROAD TRANSPORT

3.1. External costs of road transport

The existence of external *costs* of road transport is in fact beyond dispute. In Fig. 2, the main external costs of road transport are roughly classified along two dimensions. On the vertical axis, a distinction is made between external costs that road users pose upon each other: *intrasectoral external costs*; and external costs that are posed upon the rest of the society: *environmental externalities*. A further distinction is made between environmental externalities in the *ecological* sense (i.e., harming natural environments) and in a somewhat different sense, concerning *social* environments. On the horizontal axis, the external costs are divided into (a) effects that arise from *actual transport activities*; (b) external costs that arise when vehicles are *not in motion* and (c) external costs that are closely related (but not solely attributable)[2] to the existence of *infrastructure*. The shaded areas indicate the first order incidence of the external costs. Some external costs exhibit both intrasectoral and environmental properties. For instance, external accident costs are to a certain extent posed upon fellow car users (*the intrasectoral incidence*); partly on people outside this population (the *social environmental incidence*) and may finally have an *ecological environmental incidence* when transport of hazardous substances is involved. The second order incidence of the externalities can occur at different scale levels. For example, congestion usually increases emissions per vehicle-kilometre. The severeness of these external costs will to a large extent be time and place sensitive but at least in a *qualitative* sense, Fig. 2 indicates that road traffic indeed causes a wide range of external costs.

3.2. External benefits of transport?

There seems to be some confusion on the question of whether transport yields important external benefits. Especially representatives of the automobile industry and related sectors often claim that the external benefits of road transport largely exceed its external costs, thus casting doubt on the necessity to restrict car use. For instance, according to Diekmann (1991) (auto-)mobility "contributes towards the quality of life . . . (and) . . . the overall growth in prosperity and leisure time since World War II could never have been accomplished without mass-motorization" (p. 39).

However important though the contribution of road transport to general well being may be, the crucial question is of course whether such benefits are indeed external. If so,

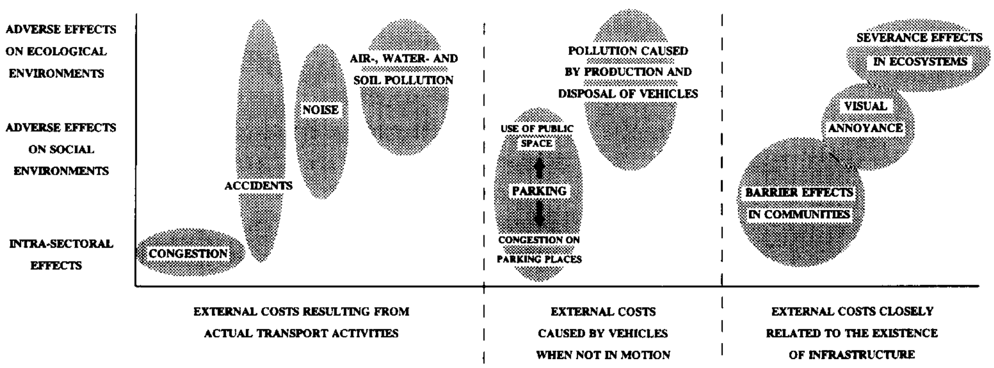

Fig. 2. A typology of external costs of road transport.

[2]We do not consider environmental externalities resulting from the mere presence of infrastructure in this article.

Pareto efficiency might require encouragement of car use by means of Pigouvian subsidies or through the creation of Coasian markets where the non-paying profiteers could compensate road users in order to seduce them to increase their mobility. External benefits would at least to a certain extent compensate for the external costs of road transport. Therefore, it is important to examine the suggested external benefits of road transport.

First, transport obviously plays a vital role in modern economies. However, the interrelations of the transport sector with other actors and sectors generally take place on well defined markets. Often claimed *external benefits* of road transport such as lower production costs and consumer prices, greater variability in product choice, and faster delivery are actually *pecuniary benefits*. These benefits essentially result from lower transportation costs (or greater efficiency) of road transport in comparison with other modes, and will eventually accrue to the final consumers of the transported goods (assuming no market distortions elsewhere in the economy). Such effects (the realization of the increase in the consumer surplus in Fig. 1D) require no government intervention because social welfare can not be increased by stimulating the activity. Therefore, these effects do not compensate for road transport's external costs.

Second, *spin-off effects* of road transport in terms of value added or employment in related economic sectors (vehicle manufacturing or maintenance, oil industry, etc.) do not provide a sound economic base for not restricting road transport to its optimal levels. Insofar as these effects result from excessively high levels of road transport, such general economic goals should preferably be aimed at by means of less distorting instruments.

Third, there is a large group of unpriced external relations associated with transport that do not qualify as external benefits. Such effects for instance occur when people receiving guests derive benefit from the visit, but do not actually compensate for the associated travel costs. Usually however, this involves either *barter* behaviour or *altruistic* behaviour. In the first case, the travelling person expects a counter visit in the (near) future and therefore both parties do – implicitly – agree not to pay for each others' travel costs. Alternatively, the visitor takes the utility of the receiving person into account. Insofar as the receiving person finds that he/she is not being paid enough visits, he/she may be expected to reveal his/her willingness to pay for more visits directly to the visitor. Neither form of individual utility maximizing behaviour is inconsistent with Pareto optimality and social welfare can therefore, again, not be increased by encouraging such behaviour.

Furthermore, the benefits of *infrastructure* are often confused with external benefits of road transport itself. For instance, such benefits concern the effects of infrastructure on (regional) economic development and employment levels. Rietveld (1989) asserted that, according to the theory, the economic effects of the building of new infrastructure would be moderately positive (if infrastructure was initially lacking), neutral (if infrastructure already exists), or even negative (redistributional effects between regions). Any considerations on such effects of road infrastructure may very well play an important role in decisions on infrastructure investments[3] (e.g., in cost-benefit analyses) but should be clearly separated from the actual *use* of the infrastructure: the road transport activities. This point can again be clarified with the aid of Fig. 1D. Apart from showing the pecuniary benefits of road transport as such, this diagram can be used also to demonstrate lower costs for road users resulting from infrastructural investments. The (shaded) increase in the consumer surplus now reflects the benefits of infrastructural improvements as enjoyed by the users of the infrastructure, for instance, in terms of gains in travel times. However, these gains do of course by no means compensate for road transport's external costs. Here, the investment in additional infrastructure is socially desirable if the increase in the bold triangle (i.e., the increase in the social surplus) is large enough to cover the investment's social costs, provided the infrastructure is used at the socially optimal level. Any investment in road infrastructure will of course only yield *maximum* benefits when it is used *at*, and not *beyond* the socially optimal level of transport.

[3]Because of its public good character, the supply of infrastructure at efficient levels usually requires public provision.

A comparable category of often claimed external benefits of transport is the increased security resulting from better accessibility for fire engines, police cars, ambulances, etc. However, the increased accessibility for such services is to be attributed to the infrastructure only, and certainly *not* to the actual transport activities. On the contrary, the higher the mobility, the more such services will suffer from congestion. Consequently, if there is any form of an external effect of transport in this respect, it is an external cost rather than a benefit.

In summary, we are not able to detect any significant external benefits of road transport activities (apart perhaps from the benefits enjoyed by "car-spotters"). Because on the other hand, considerable external costs are involved, road transport may be expected to be beyond its socially optimal level. Road traffic indeed puts an excessive burden on our societies, and government intervention that aims at reducing the external costs of road transport will therefore generally increase social welfare.[4] Empirical work toward the external effects of road transport can therefore be restricted to the external *costs* of road transport. The following section presents a conceptual framework which is particularly suitable for the analysis of *environmental* externalities.

4. ENVIRONMENTAL EXTERNAL COSTS OF ROAD TRANSPORT: CONCEPTUAL ISSUES

In Fig. 1, a very basic interpretation of externalities was presented. The actual level of external costs depends on the level of the activity (Q), only. In order to reduce the external cost, the producer of the effect can only reduce his/her activity. On the other hand, the victim can only passively suffer from the damage done to him/her. In a more realistic setting, however, one has to take into account that the producer may also reduce the external cost by performing *abatement* activities and the victim might protect himself against the negative effect by means of *defensive* measures. In this way, both abatement and defensive *technologies* can explicitly be taken into account in the analysis. This approach is in particular relevant for investigating the environmental (both ecological and social) externalities of road transport, because possibilities for defensive and abatement activities are indeed present in these cases. For instance, cars may be equipped with cleaner or more silent technologies; victims of road transport noise annoyance may decide to protect themselves by means of double glazing; etc.[5]

In Verhoef (1993), the following general external cost function is presented to describe such a setting:

$$\mathrm{EC} = \mathrm{EC}(Q,D,A) \tag{1}$$

where EC is the external cost; Q is the level of the externality causing activity; D is the level of the victim's financial outlays on defensive measures; and A is the level of the producer's financial outlays on abatement activities.

Whereas in the basic setting the social cost could be interpreted as the sum of the private cost and the external cost, in this new setting the following concepts may be distinguished: (a) the *gross private cost* of an activity is the sum of the private production cost (PC) and the outlays on abatement activities (A); (b) the *gross external cost* of an activity is the sum of the net external cost (EC) and the induced outlays on defensive activities (D); (c) the *social cost* of an activity is the sum of the gross private cost and the gross external cost.

[4]This will in particular be true when the current taxes on car use are not sufficient to cover both the optimal Pigouvian tax and the social overhead costs of road use (e.g., maintenance and depreciation of road infrastructures; costs of traffic police).

[5]This approach is less suitable for road transport's intra-sectoral externalities, such as congestion or accidents. First, there is simply limited scope for abatement and defensive measures in these cases. Furthermore, the explicit distinction between the producer(s) and victim(s) of an external cost is less meaningful when these two are united in one actor (i.e., the road user).

This approach has some important implications for the analysis of an activity's[6] external or social cost. Such analyses may concern several research questions, the most obvious two being the questions of *efficiency* and *equity*.

4.1. The efficiency effect of external costs

The first possible research question when external costs occur is the assessment of the socially *optimal* level of an activity. Although this question is highly artificial for the case of road transport because such optimal levels will be time and place related, it is interesting to see the implications of the general external cost function for the interpretation of the concept of *optimality*. Let us reconsider the general external cost function given in (1), and assume that the following functional characteristics, representing the most likely case, apply:

$$EC_Q > 0 \text{ and } EC_{QQ} \geq 0 \tag{2a,b}$$

$$EC_D < 0 \text{ and } EC_{DD} > 0 \tag{2c,d}$$

$$EC_A < 0 \text{ and } EC_{AA} > 0 \tag{2e,f}$$

that indicate positive nondecreasing marginal external cost of the activity and positive diminishing marginal effectiveness of both kinds of measures. In addition, it may be postulated that:

$$EC_{DQ} = EC_{QD} < 0 \tag{2g}$$

$$EC_{AQ} = EC_{QA} < 0 \tag{2h}$$

$$EC_{AD} = EC_{DA} > 0 \tag{2i}$$

The first two relationships ((2g) and (2h)) indicate that at higher levels of the activity, outlays on defensive and abatement actions will have more impact in terms of reducing the external cost; at higher levels of defensive or abatement outlays, a rise in the activity level causes smaller increases in the external cost. The third relationship (2i) states that at higher levels of defensive activities, the effect of increasing abatement will be smaller and vice versa.

The producers' welfare function is given by:

$$W^P = PB(Q) - PC(Q) - A = NPB(Q) - A \tag{3}$$

where: PB(Q) is the private benefit of the activity; PC(Q) is the private cost of the activity; NPB(Q) is the sum of these two: the net private benefit of the activity.

Very general, we assume diminishing marginal net private benefits:

$$NPB_{QQ} < 0 \tag{4}$$

The victims' welfare function is:

$$W^V = - EC(Q,A,D) - D \tag{5}$$

Finally, social welfare is given by the sum of the individual welfare functions:

$$W = W^P + W^V = NPB(Q) - EC(Q,A,D) - A - D \tag{6}$$

Social welfare maximization (efficiency) is now realized according to the following first order conditions:

[6]The term *activity* used in this section may be interpreted as road transport activities in vehicle kilometres. Likewise, the term *producers* may refer to car drivers.

$$W_Q = 0 \Rightarrow EC_Q = NPB_Q \tag{7a}$$

$$W_A = 0 \Rightarrow EC_A = -1 \tag{7b}$$

$$W_D = 0 \Rightarrow EC_D = -1 \tag{7c}$$

These three conditions must simultaneously be met to secure the prevalence of the social optimum (Pareto efficiency).[7] An intuitive interpretation of these results is that in the optimum, a reduction in the external cost is equally expensive for the three different ways of achieving it (i.e., a reduction in the level of the activity, or increases in abatement or defensive outlays). In each case, the marginal value of reducing the external cost is equal to the marginal cost of accomplishing such reductions. Hence, the three options for reducing the external costs are equally efficient in the optimum.[8]

In Verhoef (1993), it was investigated whether the producers' behaviour [i.e., maximization of (3)] and the victims' behaviour [i.e., maximization of (5)] are expected to be efficient [i.e., in line with equations (7a–c)]. It is shown that the victims can in general be expected to exhibit efficient behaviour as long as compensation does not take place. However, the producers' behaviour will in general not be efficient: a too large level of production will be chosen and a zero level of abatement outlays will result. The policy implications are clear: government intervention should in the first place focus on reducing the activity (Q) and stimulating abatement (A). Furthermore, one should be careful when it comes to compensating the victims of externalities.

4.2. The equity effect of external costs

A second possible research question concerning external costs is the assessment of the (implicit) redistributive effect. This "burden" that an activity puts upon the rest of the society may be thought of as the activity's *unpaid bill.* This research question may seem less interesting than the theoretical concept of optimality. Still, the empirical research that has been carried out thus far on road transport's external costs (see Section 5) belongs to this category. This can to a large extent be attributed to the fact that this research question is somewhat easier to answer than the question of optimality. An empirical estimation of the functional relationships of equations (6) and (7) will yield considerable difficulties. Furthermore, optimality in road transport is a highly hypothetical concept because optimal levels of car use will be time and place related. There is no single overall indicator for a society's optimal level of road transport. Finally, a close relationship between the question of optimality and the actual redistributive effect exists. Assuming constant marginal external costs, the average gross external effect will give an indication for the average level of optimal Pigouvian taxes on road transport (i.e., the optimal road price). Whatever the reason for investigating the implicit redistributive effect due to road transport may be, the *gross external cost* [EC + D in equation (6)] is the relevant measure in this case.

The atomistic structure of road transport markets has an important implication for the assessment of the redistributive component of external costs of road transport. Figure 2 already showed that these effects take place at different *scale levels*. The main distinction made was between *intrasectoral* and *environmental* external costs. As a result, the estimated value of a (partly) intrasectoral external cost depends on the scale level chosen. This can be illustrated by the case of external accident costs. A considerable part of the accident cost which are external at the individual level are costs which are internal at the sectoral level. These are the costs that car drivers user poses on fellow car drivers.

[7]The resulting extremum will of course only be a welfare maximum if the associated Hessian satisfies the necessary criteria (i.e., the principal minors duly alternate in sign, the first one being negative).

[8]A quite different approach toward the definition of social costs is suggested by Quinet (1991). There, the social cost of a certain form of *nuisance* (e.g., noise annoyance), rather than the social costs of the *activity* itself, is defined as the sum of (a) the victims' willingness to pay for a reduction of the nuisance to the zero nuisance level; (b) the production value forgone by the producers in comparison with the value realized at the maximum nuisance level; (c) the total cost of other abatement outlays by the producers. Then, the minimum level of the social costs defines the social optimum. In our definition, the minimum level of social cost is of course zero: when neither the activity itself, nor any form of abatement and defensive activities takes place.

Consequently, there is a logical fallacy in simply adding the values of environmental external costs to the values of external costs which are to a large extent intrasectoral. At least, it should be recognized that such exercises do not yield figures indicating the burden of road transport upon the rest of the society.

Next, the framework just presented is applied in the evaluation of some recent empirical estimates of external costs of road transport.

5. EMPIRICAL ESTIMATES OF EXTERNAL COSTS OF ROAD TRANSPORT

The two most widely studied environmental external costs of road transport are noise annoyance and environmental pollution. This section provides an overview of the results obtained in such studies. Furthermore, considerable effort has been put into the assessment of the costs of road transport accidents. Because these costs are not purely environmental but involve considerable intrasectoral costs, they require a different approach. Therefore, they are addressed separately.

5.1. Noise annoyance and air pollution

Tables 1 and 2 summarize the findings of recent empirical estimates of the external costs of road transport in terms of noise annoyance and air pollution. None of the studies mentioned explicitly focuses on *optimality* in road transport. The research question typically involves the *redistributive (equity) effect* due to the external costs. According to Section 4, the gross external cost—the sum of the net external cost and the outlays on defensive activities (EC + D)—is the relevant measure in those cases. However, in existing empirical research this distinction between (net) external cost and outlays on defensive

Table 1. Selected estimates of external costs of (road) traffic noise

Authors	Year	Country	Absolute Value	Percentage of GDP**	Method
Ringheim*	1983	Norway	Kr. 180 mln.	0.22%	Loss in property value
			Kr. 135 mln.	0.17%	Sleep loss
			Kr. 55 mln.	0.07%	Existing protection
			Kr. 100 mln.	0.12%	Potential vehicle protection program
Wicke*	1987	FGR	DM 3 bln.	0.15%	Productivity losses
			DM 29.3 bin.	1.45%	Lower property values (30 dB(A) norm)
IRT*	1983	France	FF 12–91 bln.	0.30–2.27%	Outside insulation costs for 50–40 dB(A) norm
Lambert*	1986	France	FF 2 bln.	0.04%	Loss in property values
UIC*	1987	NL	DFL77 mln.	0.02%	Government expenditure on abatement
Opschoor*	1987	NL	DFL 80 mln.	0.02%	Falling property values
Sharp e.a.*	1976	UK	£14.2 bln.	11.18%	Reducing traffic noise by 10 dB(a)
Quinet	1989	General		0.1%	Comparison of studies
Kanafani	1983	Europe		0.1–0.2%	Comparison of studies
		USA		0.06–0.12%	
Bouladon	1979	General		0.3–1.0%	Abatement at source
Bleijenberg	1988	NL	DFL 130–350 mln.	0.03–0.08%	Extra prevention and remaining property value decline
V.d. Meijs	1983	NL			Potential programs:
			DFL 100–300 mln.	0.03–0.08%	Insulation
			DFL 450–900 mln.	0.12–0.24%	Abatement at source
Dogs e.a. (PLANCO)	1991	FGR	DM 0.84 bln.	0.03%	Roads: avoidance cost
			DM 0.84 bln.	0.03%	Rail: avoidance cost
			DM 12.8 bln.	0.52%	Roads: WTP
			DM 5.5 bln.	0.22%	Rail: WTP
Grupp	1986	FGR	DM 0.7–2.0 bln.	0.04–0.10%	Avoidance cost
			DM 0.4–0.9 bln.	0.02–0.05%	Falling house prices

*As quoted by Quinet (1989); percentage of GDP recalculated on basis of IMF (1991); **Bases on GDP figures in IMF (1991).

Table 2. Selected estimates of external costs of (road) traffic air pollution

Authors	Year	Country	Absolute Value	Percentage of GDP**	Method
VROM*	1985	NL	DFL 520–830 mln.	0.12–0.20%	30% of total damage to health, agriculture, and buildings due to air pollution
Shulz*	1987	FGR	DM 3–6 bln.	0.15–0.30%	30% of total damage to health, buildings, and forests due to air pollution
			DM 5–16 bln.	0.25–0.79%	30% of total willingness to pay for clean air
Perrin Pelletier*	1984	EC	$17.5 bln.	0.5%	Cost of complete introduction of catalytic converters
Quinet	1989	General		0.4%	Comparison of studies
Kanafani	1983	Europe USA		0.16–0.21% 0.3%	Comparison of studies
Bouladon	1979	General		0.6–1.2%	Vehicle price increases plus unclear extra charge
Bleijenberg	1988	NL	DFL 1200–1700 mln.	0.27–0.38%	Prevention at source plus remaining damage
V.d. Meijs	1983	NL	DFL 100–1200 mln.	0.03–0.31%	Abatement at source for various standards
Dietz	1990	NL	DFL 619 mln.	0.14%	Net government costs of abatement of environmental pollution (incl. noise; all modes)
McKinsey	1986	NL	DFL 600 mln.	0.14%	Prevention plus damage (including noise)
Dogs e.a. (PLANCO)	1991	FGR	DM 12.1 bln.	0.49%	Roads: damage cost
			DM 0.2 bln.	0.01%	Rail: damage cost
			DM 22.3 bln.	0.91%	Roads: WTP
			DM 0.3 bln.	0.01%	Rail: WTP
Grupp	1986	FGR	DM 4.3–10.3 bln.	0.22–0.53%	Damage cost

*As quoted by Quinet (1989); percentage of GDP recalculated on basis of IMF (1991); **Bases on GDP figures in IMF (1991).

activities is not explicitly recognized. On the contrary, the research carried out thus far broadly falls apart in the following two categories: *short cut approaches*, where outlays on actual or potential defensive or abatement programs are taken to represent the external cost, and *valuation approaches* where so-called *valuation techniques* are used to estimate the *net* external cost. The only exceptions to this rule are McKinsey (1986) and Bleijenberg (1988) for the Netherlands. In both studies, the external costs were estimated as the sum of extra prevention (both defensive and abatement) measures plus the remaining damage. However, in this way the *optimal* rather than the *actual* gross external effect is estimated. Furthermore, the determination of optimality is unclear in these studies.

Usually, therefore, the figures in Tables 1 and 2 are underestimations of the *gross external cost*, representing only either of its two components (EC or D). Further deviations from the estimation of the gross external cost are those studies which focus on the level of abatement activities (A).

5.1.1. Short cut approaches

In short cut approaches, the cost of actual or potential defensive or abatement programs are taken to represent the external costs. Two such strategies are distinguished.

In the first approach, *actual defensive (or abatement) outlays* are interpreted as representing the victims' or social willingness to pay for reducing annoyance to acceptable levels and therefore representing the external cost. Although market data on victims' expenditures on defensive measures may indeed be used for inferring their valuation of an external cost (the household production function approach is based on that notion), this approach leads to serious underestimations of the *gross* external cost. Apart from the unlikely case where these outlays reduce the net external cost to a zero level, the *remaining net external cost* is neglected.[9]

Another, more often used short cut approach is to value an external effect at the theoretical cost of *potential abatement or defensive programs*, necessary to reduce the externality to a "reasonable" level. This approach also suffers from important methodological shortcomings. First, the remaining externality—after the program is carried out—is again valued at a zero level. Furthermore, the valuation of the intended reduction in net external cost is higher than the cost of the proposed programs—which should of course be the fundamental economic reason for undertaking the programs in the first place. Finally, this approach suffers from circular reasoning, because the "optimal" level of the remaining externality is more or less arbitrarily chosen—whereas it should result from weighing of the costs of such programs against the benefit in terms of reductions in the external costs [see the first order conditions in equation (7)]. This last point is illustrated by the outcomes of the IRT noise study for France, where the more stringent of the two norms specified yields an external cost estimate which is six times as high as compared with the other norm. Likewise, Van der Meijs (1983) reported external costs of noise and road traffic air pollution in The Netherlands which differ by factors 9 and 12, respectively depending on the standards chosen.[10]

5.1.2. Valuation approaches

The second category concerns studies which apply *valuation techniques* to estimate the external costs of noise and pollution. Such techniques, which aim at estimating the monetary value of (by definition unpriced) externalities, originate from environmental economics. Many of such techniques have been developed over the last decades. A main distinction that can be made with regard to valuation techniques is between *nonbehaviourial linkage techniques* and *behaviourial linkage techniques* (Mitchell & Carson, 1989).

Nonbehaviourial techniques seek to establish a physical damage function (for nonliving receptors) or a dose-response relationship (for living receptors). The quantitative effects estimated are multiplied with relevant market prices, which is why these techniques are sometimes referred to as money transaction techniques. Practical applications of these nonbehaviourial techniques include studies toward the costs of environmental degradation (e.g., air pollution) in terms of physical depreciation of buildings, in terms of damage done to agricultural production, or estimates of the cost of illness.

Behaviourial linkage techniques are "based on some form of behaviourial linkage between a change in an amenity and its effects" (Mitchell & Carson, 1989, p. 75). An important distinction within this group is between observations on *surrogate* and on *hypothetical* markets. The surrogate market approach "looks for a market in which goods or factors of production (especially labour services) are bought and sold, and observes that environmental benefits or costs are frequently attributes of those goods or factors" (Pearce & Turner, 1990, p. 142). Hedonic approaches, the travel cost approach and the (household) production function approach belong to this category (see Johansson, 1987). *Hypothetical approaches* have in common that respondents are placed in a simulated market in which they can express their (hypothetical) valuations of improvements or deteriorations in environmental quality. In its most direct form, the *contingent valuation method* (CVM), people are directly asked for their valuation of an environmental good by means of a questionnaire approach. In spite of the methodological difficulties associated with CVM, Mitchell and Carson (1989, p. 295) conclude that the outcomes are sufficiently reliable and valid for empirical use. Likewise, Pearce and Turner (1990) called the evidence on the validity of CVM "reassuring" (p. 153).

[9]As a matter of fact, assuming all relevant functions continuous, victims will maximize their utility by choosing the expenditure bundle for which the marginal utility of each good is equal to its price. Because the marginal utility of defensive outlays is found in the reduction of the net external cost, this means that in the consumption optimum there will still be positive utility associated with marginal reductions in the external cost. Consequently, the net external cost is generally greater than zero (assuming positive marginal utility with respect to all consumption goods).

[10]The extreme outcome on external noise costs reported by Sharp for the United Kingdom can not only be attributed to the particular specification of the norm but in particular to the fact that no correction is made for the number of years over which the outlays should be spread.

In comparison, a major drawback of the nonbehaviourial linkage techniques is that the victims' valuation of the effect is not considered at all. Mitchell and Carson (1989) observed in this respect that there is little theoretical basis for the use of these techniques in welfare economics, because the damage functions are not directly related to the consumers' utility functions. Furthermore, nonbehaviourial techniques result in an estimate of the *user value* of environmental goods at best and are not capable of inferring *non-use values* (see Pearce & Turner, 1990). Still, nonbehaviourial techniques receive much support because the figures produced seem to be "harder" (see Hoevenagel, 1991).

As far as the behaviourial techniques are concerned, the surrogate market techniques will almost by nature have limited applicability since for many environmental effects no apt "surrogate market" exists. Moreover, if such markets do exist, they tend to be heavily regulated (property markets, labour markets), which makes them less applicable for surrogate market valuation techniques. Furthermore, also these techniques are capable of measuring the user value of environmental goods only. Hypothetical market approaches have the broadest scope of all techniques mentioned. However, they provide the most "soft" results, because hypothetical rather than "real" behaviour is investigated.

Clearly, from a theoretical point of view, behaviourial valuation methods deserve preference. However, it cannot in general be said whether one particular group of valuation methods is superior over the others. Each technique may be more or less applicable in different situations. Moreover, Schechter (1991) even suggested that behaviourial and nonbehaviourial methods should not be seen as substitutes but rather as complements. The reason is that nonbehaviourial methods can measure *social costs*, which will include components that may be expected not to enter into the consumer's optimization process (e.g., paid sick leave). Contingent valuations essentially measure the *psychological cost* associated with the public disamenity. "If this were largely the case, then no double counting would be involved if contingent valuations, or at least a major part of them, were added to cost of illness or household production function valuations" (Schechter, 1991).

In empirical work on the external costs of road transport, the nonbehaviourial linkage techniques are relatively often employed (concerning noise: Wicke, 1987, for Western Germany; concerning air pollution: VROM, 1985, for The Netherlands; Shulz, 1987 and Grupp, 1986, for Western Germany).

Furthermore, hedonic property techniques have found ample use as far as the estimation of external costs of noise annoyance is concerned. This can be explained by the fact that noise annoyance is in general a strongly localized effect, which makes such hedonic property techniques particularly apt. Nelson (1982) and Pearce and Markandya (1989) concluded on basis of comprehensive literature studies that property values will drop by 0.15%-1.3% per decibel (dB(A) Leq) extra noise annoyance. It is worth noting that hedonic property studies are also sensitive to the specification of the "zero-annoyance level" (see for instance the relatively high estimate of Wicke, 1987).

Recent use of hypothetical (WTP: willingness to pay) methods suggests that this relatively new approach may yield outcomes twice as high for air pollution (see Shulz, 1987; Dogs, 1991) and even 15 times higher for noise annoyance (Dogs, 1991) as compared with the results of other techniques. This may indicate either serious underestimations resulting from other techniques, or methodological problems in CVM estimations.

Again, these valuation approaches tell only half the tale when it comes to measuring the gross external costs. Only the net external costs are estimated.

5.2. Accidents

The interpretation of external costs of road traffic accidents is a bit tricky. First, as outlined in Section 3, the estimated level critically depends on the particular scale level of the analysis.[11] This special characteristic of road transport accidents implies that it is not

[11]For example, Neuenschwander, Sommer and Walter (1991) estimated the external accident costs of car traffic at 1488 million Swiss Francs when considered at the individual level, and at 789 million Swiss Francs a (±50%) when considered at the mode level. For rail traffic these figures were 59 million and 5 million (±8%), respectively.

Table 3. Selected estimates of social costs of (road) traffic accidents

Authors	Year	Country	Absolute Value	Percentage of GDP*	Method
Quinet	1982	FRG		2.54%	Government answer
	1987	NL		1.67%	National budget
	1986	UK		1.5%	Quoted by Button
	1985	France		2.6%	Le Net
Kanafani	1983	Europe		1.5–2.5%	Comparison of studies
		USA		1.5%–2.5%	
Bouladon	1979	USA		0.4–0.9%	Costs not covered by insuranc
		Europe		0.25–0.9%	human life: $100,000 average injury: $4,000
Bleijenberg	1988	NL	DFL 1.4–2.4 bln.	0.31–0.54%	Damage, production losses, medical, prevention, and le costs not covered by insura or tax
V.d. Meijs	1983	NL	DFL 1.5–3.2 bln.	0.39–0.84%	See above, using different val of life estimations
Hoogeboom en Rietveld	1992	NL	DFL 5.0 bln.	1.06%	Social cost minus insurance covering
Dubus	1986	Belgium	BF 105 bln.	2.06%	Damage, lost production, lega and insurance cost
Dogs e.a. (PLANCO)	1991	FGR	DM 19.6 bln.	0.80%	Production losses and damag not avoidance and sufferin cost
Grupp	1986	FGR	DM 39.7–46.2 bln.	2.04–2.38%	Value of life: DM 1.1 mln. Personal and physical dam
Neuenschwander	1991	Switzerland	SF 5,379 mln.	1.70%	Social cost
			SF 1,488 mln.	0.47%	Ext. cost, indiv. level
			SF 789 mln.	0.25%	Ext. cost, mode level

*Bases on GDP figures in IMF (1991).

possible to interpret "external accident costs" as being purely environmental. The common practice of adding accident costs to costs of air pollution and noise annoyance is therefore questionable. Furthermore, it is difficult to determine the costs that are eventually borne by the actors responsible for the accidents—which might be interpreted as *internal* accident costs. It is often not possible to identify one single responsible actor (consider chain crashes). Moreover, not all costs connected to the responsible actor are indeed internal. For instance, his/her death or injuries may affect both the well being of his/her friends and relatives (in terms of pecuniary and psychological costs) and invoke social costs (in terms of lost production, medical costs, etc.).

Given these fundamental problems, most researchers prefer speaking of the social costs of road transport accidents. These are usually defined as total accident costs minus insurance coverage.[12] This interpretation of social costs does not satisfy the definition of social costs in Section 4. The cost components associated with traffic accidents usually include: physical damage to vehicles, infrastructure, properties, and natural environment; legal, police, and emergency service costs; costs of injuries and fatalities, such as medical and funeral costs; psychological costs of pain and suffering; production losses.

A fundamental problem in the assessment of social accident costs concerns the valuation of life, pain, and suffering, which are unavoidable inputs in such undertakings. These issues of course involve bizarre elements. For example, when the (expected) net economic productivity of a person is taken to represent the social value of his/her life (which is not an unusual approach), negative values of life for elderly or jobless people may result. The policy implications are rather odd, indeed. Therefore, from a theoretical point of view, it might be preferable to infer *ex ante* valuations of changes in physical risks. Hammerton, Jones-Lee, and Abott (1982) advocated this approach and conclude by suggesting a value of life of £250,000. As may be expected, the literature provides us

[12]It is often argued that accident costs are to a considerable extent "internalized" by means of insurance coverage. However, the concept of internalization must not be misunderstood in this respect. Because insurance premiums usually involve an almost fixed yearly payment, largely independent of kilometres driven, insurance coverage may lead to compensation but not to optimization of external accident costs.

with a wide range of estimates on the value of life. Ka'geson (1992) reported the outcomes of several studies conducted throughout Europe. The figures range from 12,280 ECU (Portugal, value of gross earnings) to 1,667,246 ECU (Switzerland, social willingness to pay) per road victim. The absolute minimum value reported that we were able to trace amounts to DFL 2400 ($\pm$1000 ECU) for The Netherlands, which are the friction costs of replacing a deceased in the labour process (NEI estimate, as quoted by Voskuil en Klooster, 1991).

Table 3 presents an overview of recent estimates of social costs of (road) transport accidents. Because these figures concern social rather than external accident costs, one should be very careful adding these figures to the estimates of environmental external costs such as noise annoyance and air pollution.

6. CONCLUSION

The results of empirical studies toward the external costs of road traffic noise and air pollution presented in Tables 1 and 2 in general provide serious underestimations of the gross external costs. First, either the net external cost or the defensive measures are usually estimated, instead of the sum of those two. Furthermore, the valuation techniques employed may often yield downward biased estimates. In particular, relatively recent hypothetical market studies suggest much higher values. In addition, as argued by Schechter (1991), in order to assess the total net external costs it might in some cases even be necessary to add the outcomes found by applying different valuation techniques.

Apart from these theoretical objections there are some practical reasons why the environmental external costs of road transport will generally be higher than the figures given in Tables 1 and 2. First, concerning the costs of air pollution, no empirical effort has been made so far to estimate the costs associated with the emissions of CO_2, the main contributor to the Greenhouse Effect. Moreover, with reference to Fig. 2 it is clear that some important (ecological and social) environmental costs have been left out. The reason is simply that, as far as we know, no estimations have been carried out so far.

All in all, the often quoted figures given by Quinet (1989) in his important survey paper—external costs of road transport amounting to 0.1% of Gross Domestic Product (GDP) for noise and 0.4% for air pollution for OECD countries—may be serious underestimations of the true external costs of road transport. The acceptance of hypothetical market approaches alone already suggests that these values may have to be multiplied by a factor 8 for noise (compare Dogs, 1991); and a factor 2 or 3 for air pollution (compare Schulz, 1987; Dogs, 1991) if, of course, trust is put in the validity of hypothetical market approaches.

Finally, the determination of (external) accident costs of road transport is fraught with methodological difficulties. The figures in Table 3 concern road transport's social rather than external accident costs, and cannot simply be added to the estimations of external costs of noise and air pollution in order to infer the external costs of road transport.

Acknowledgements—Sponsoring from the VSB-fonds is gratefully acknowledged. I thank Jeroen van den Bergh, Peter Nijkamp, and Piet Rietveld for valuable comments on earlier versions of this paper.

REFERENCES

Baumol, W. J. and W. E. Oates (1988). *The theory of environmental policy* (2nd ed.). Cambridge University Press, Cambridge.

Bleijenberg, A. N. (1988). *Waardering van Negatieve Externe Effecten van het Autoverkeer*. Centrum voor energiebesparing en schone technologie. Delft.

Bouladon, G. (1979). Costs and benefits of motor vehicles. In: OECD *Urban Transport and the Environment*, Paris.

Button, K. J. (1990). Environmental externalities and transport policy. *Oxford Review of Economic Policy*, 6: 61–75.

Diekmann, A. (1991). Kosten en baten van de auto: Poging tot een juiste afweging. *Mobiliteitschrift*, 91/7, 8:3–11. Stichting Weg.

Dietz, E. J. (1990). Milieukosten van het verkeer 1985-1988. *Kwartaalbericht Milieu* 90/1: 9-13, Centraal Bureau voor de Statistiek, Den Haag.
Dogs, E., Ellwanger, G. & Platz, H. (1991). Externe Kosten des Verkehrs. *Die Bundesbahn* 91/1:39-45.
Dubus, P. (1986). *Calcul des coûts externes des transports terrestres*. Société Nationale des Chemins de fer Belges, Bruxelles.
Van Gent, H. A. & Vleugel, J. M. (1991). Autoverkeer en -vervoer: externe baten?? In P. T. Tanja (ed.) *Vervoersplanologisch Speurwerk 1991*. Delft, C.V.S.
Grupp, H. (1986). Die soziale kosten des verkehrs, Teil I und II. *Verkehr und Technik*, 9/10:359-366, 403-407. Erich Schmidt Verlag, Berlin.
Hammerton, M., Jones-Lee, M. W. and Abott, V. (1982). The consistency and coherence of attitudes to physical risk. *J. Transport Economics and Policy*, 1982:181-199.
Himanen, V., Nijkamp, P. & Padjen, J. (in press). Transport mobility, spatial accessibility and environmental sustainability. In: P. Nijkamp (ed.) *Europe on the Move*. Aldershot, Avebury.
Hoogeboom, J. M. & Rietveld, P. (1992). *Maatschappelijke kosten van verkeersongevallen*. Unpublished, Free University, Amsterdam.
Hoevenagel, R. (1991). *A comparison of economic valuation techniques*. Paper presented at the Charmey-workshop, Switzerland.
IMF (1991). *International financial statistics: Yearbook 1991*. Washington, DC.
Johansson, P-O. (1987). *The economic theory and measurement of environmental benefits*. Cambridge University Press, Cambridge.
Ka'geson, P. (1992). *Internalising social costs of transport: Preliminary study*. European Federation for Transport and Environment and Swedish Society for Nature Conservation, Stockholm.
Kanafani, A. (1983). *The social cost of road transport*, Draft. OECD, Paris.
McKinsey et al. (1896a). *Afrekenen met files*. Ministerie van Verkeer en Waterstaat, Den Haag.
McKinsey et al. (1986b). *Afrekenen met files: Bijlagen*. Ministerie van Verkeer en Waterstaat, Den Haag.
Meijs, A. G. M. van der (1983). *Auto en Overheid* Onderzoeksreeks Nr. 9, Instituut voor Onderzoek van Overheidsuitgaven, Den Haag.
Mishan, E. J. (1971). The postwar literature on externalities: An interpretative essay. *J. Economic Literature*, 9:1-28.
Mitchell, R. C. & Carson, R. T. (1989). *Using surveys to value public goods: The contingent valuation method*, Resources for the Future. Washington, DC.
Nelson, J. P. (1982). Highway noise and property values: A survey of recent evidence. *J. Transport Economics and Policy*. 1982:117-138.
Neuenschwander, R., Sommer, H., & Walter, F. (1991). *Soziale Kosten von Verkehrsunfällen in der Schweiz*. ECOPLAN, Wirtschafts- und Umweltstudien, Bern.
Pearce, D. W. & Markandya, A. (1989). *Environmental policy benefits: Monetary valuation*. OECD, Paris.
Pearce, D. W. & Turner, R. K. (1990). *Economics of natural resources and the environment*. Johns Hopkins University Press, Baltimore, MD.
Quinet, E. (1989). *The social cost of land transport*. Draft, OECD, Paris.
Quinet, E. (1991). Pour une définition de la notion de coût social de l'environnement *Economie Appliquée*, 4: 67-77.
Rietveld, P. (1989). Infrastructure and regional development: A survey of multiregional economic models. *The Annals of Regional Science*, 23:255-274.
Schechter, M. (1991). A comparative study of environmental amenity valuations. *Environmental and Resource Economics*, 1:129-155.
Verhoef, E. T. (1993). *Efficiency and equity in externalities: A partial equilibrium analysis*. Mimeo, Free University, Amsterdam; Forthcoming in Environment and Planning A.
Voskuil, R. & Klooster, J. (1991). Kosten-baten opstelling: Studie effecten openstelling ringweg Amsterdam. In: P. T. Tanja (ed.) *Vervoersplanologisch Speurwerk*. Delft, C.V.S.