A Review on Monetary Valuation of the Environmental Impacts of Traffic

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ABSTRACT

Environmental resources are finite and scarce. According to the economic theory, value arises whenever satisfaction is derived to individuals. As environmental attributes represent a source of satisfaction, certain economic values are somehow associated to them. As a consequence, environmental externalities may result in costs to the economic system. Environmental valuation has become important in decision-making for appraisals of projects and schemes, as well as in the management of natural resources.

Although subject to several criticisms, many techniques have been developed to assign monetary values to environmental goods and assets. Besides, many attempts have been made on the application of such techniques for actual money estimates.

This paper presents a review on the environmental valuation of traffic-induced effects. Initially, some economic basis for environmental valuation is given, as well as a description of the main techniques, their applicability and disadvantages. A brief discussion about the economic instruments on environmental damaging activities is also presented. Further, a guidance on the valuation of some predominant adverse effects of traffic is provided.

RESUMO

Os recursos ambientais são finitos e escassos. De acordo com a teoria econômica, valor surge sempre que satisfação é derivada a indivíduos. Se atributos ambientais representam uma fonte de satisfação, certos valores econômicos são de alguma forma associados a eles. Como

consequência, externalidades ambientais podem ocasionar custos ao sistema econômico. Avaliação ambiental passou a ser importante em tomadas de decisão para análise de projetos e planos, bem como para o gerenciamento dos recursos naturais.

Embora sujeitas a várias críticas, diversas técnicas foram desenvolvidas para alocar valores monetários a bens ambientais. Além disto, muitas tentativas foram feitas no sentido de aplicar tais técnicas a fim de produzir, de fato, estimativas monetárias.

Este trabalho apresenta uma revisão sobre avaliação ambiental dos efeitos induzidos pelo tráfego. Inicialmente, uma base econômica para avaliação ambiental é reportada, assim como uma descrição das principais técnicas existentes, suas aplicabilidades e desvantagens. Uma breve discussão sobre os instrumentos econômicos aplicados a atividades que causam danos no meio ambiente é apresentada. Finalmente, uma orientação sobre avaliação monetária de alguns efeitos adversos predominantes do tráfego é fornecida.

1. Introduction

The need to maintain traffic capacity, safety, accessibility and the environment at desirable conditions generates a wide range of conflicts of interest amongst diverse segments of a community. Such conflicts reach most severe levels in urban centres, where road traffic has increased on a large scale. Transport planning projects and traffic management schemes can be derived to deal with these problems in order to preserve certain aspects of social life, such as the quality of living.

A diagnosis on the best utilization of scarce public funds together with an estimate of the likely social benefits may be essential for supporting decisions on the approval of projects. The optimum balance between expenditure and benefits is achieved through an economic evaluation of all outcomes of a scheme in a single scale. The most useful scale for integrating all diverse dimensions of evaluation into a unique measuring rod is money. As money is the natural unit on markets, monetary valuation provides the grounds for cost-benefit analyses (CBA) and it is an important tool for policies on sustainable development (Pearce, Markandya and Barbier, 1989).

The use of money as a standard measuring unit has a variety of attractions as an aid to decision making. Some of the most notorious advantages over the qualitative approach are the allowance of great consistency in benefit-cost comparative assessments and an efficient management on the use of natural resources, principally by enabling environmental considerations to be incorporated into economic appraisals. The extent to which schemes are worth being implemented, or when it is the case, preserving and improving the environment is socially worthwhile, is indicated by the comparison of monetary outputs. The derivation of environmental monetary valuation reduces the risk of subjective decisions and provides information that may assist in decisions concerning environmental regulation. Monetary valuation is a valuable tool in decision making, but it will not replace the need for judgement on CBAs.

The valuation of environmental effects brought about by the provision of transport is particularly useful for cost-benefit analyses of transport projects and traffic schemes. It is also valuable for establishing cost responsibilities, road user charges and road pricing, whenever environmental degradation is concerned. Thus, environmental economics provides the basis for monetary valuation of environmental assets, which can play a relevant role in transport planning decisions in the design of an environmentally sustainable policies.

The first official reference on environmental valuation included in the UK Government guidelines was provided by HM Treasury (1991). The Department of the Environment (1991) presents more specific guidelines on valuation techniques. This guide offers advice as to ensure that significant environmental effects are fully considered in policy appraisals. Further, the Advisory Committee on Trunk Road Assessment (Department of Transport, 1992) supports that monetary techniques will assist the assessment of the various environmental effects from transport schemes. The Department already includes some proxies to the expected monetary costs from environmental effects on its cost-benefit assessment, like mitigation measures and compensation payments.

2. Valuing the environment

The non-monetary techniques conceived to appraise environmental attributes employ a scale of perception, where standards are anchored to implicit concepts (Langdon, 1978). Most non-monetary techniques indicate the rank of alternative schemes on the order of preference, while others identify a group of acceptable alternatives by excluding the unsatisfactory ones (Rendel Planning and Environmental Appraisal Group, 1992). Such qualitative approaches enable comparisons between different alternatives and do not require a great amount of data or resources for application. Qualitative indices, such as scales of annoyance and bother, have been used as guides to the setting of environmental standards or to the purpose of compensation when standards are exceded (Langdon, 1978). The HM Treasury (1991, para. 3.18) states that ... *costs and benefits should always be listed with at least a qualitative assessment of their significance*.... The U.K. Standing Advisory Committee (Department of Transport, 1992) supports that a certain deal of qualitative description will always be essential at environmental appraisals.

However, qualitative approaches cannot express the evaluation results in a standard form for every effect accounted for, neither do they provide a common and easy understandable rod of valuation, which is highly desirable on assessments of total costs and benefits.

The rational of economic valuation for environmental attributes can be derived conceptually. Although environmental goods, assets and amenities are scarce resources, they have no explicit prices in the market, since no trade is made. Nevertheless, there is always a certain intrinsic or theoretical economic value associated to all of them, as long as they represent a source of satisfaction to individuals. Hence, value arises on social grounds, whenever a want or desire is satisfied or a preference is met. Environmental valuation is based on different concepts of value (Pearce, 1990). The *use value* is the worth of the benefit gained from the use actually made of a good, commodity, resource or asset. The value of preserving an attribute for a potential future benefit is named *option value*.

Finally, the value of the benefit originated from the mere existence of an attribute, even if no use is made at all is the *existence value*. The total economic value will therefore comprise a sum of use, option and existence values. The magnitude of values is proportional to the importance that is credited to the attribute under valuation. Environmental attributes cannot be attached to a standard worth, as they depend largely upon the circumstances of valuation. Ranges of possible values are usually preferable to point estimates.

Some environmental attributes have an immediate monetary consequence. For others, valuation still can be derived with relative ease, even if not straightforward. However, there are costs for which monetary valuation is not trivial and may depend upon extensive theoretical economic or statistical basis. Furthermore, there are costs for which valuation is impracticable and therefore they cannot be translated into money terms at all. In such cases, if failing to realistically reflect social-economic costs, the normative signficance of environmental valuation may be highly questionable.

The cost associated to the value of travel time, for instance, is of prime importance on transport research and monetary values have already been assigned to it with successful results (MVA Consultancy, 1987). However, relatively little progress has been made on the environmental management field, as practical experience has proved extremely hard to derive sensible values for environmental attributes. Monetary techniques have presented many consistency difficulties and inaccuracies of application. In many cases, environmental assessments have been limited to the identification, qualitative description, measurement and quantification of the most significant effects. In other circumstances, no consideration has been dispensed at all on decision making, mainly in relation to the most subjective or less tangible effects. Even when monetisation estimates are archieved, they could rarely be considered as the unquestionable truth. Estimates are usually conservative, reflecting only some extent of the real cost of environmental degradation. In fact, as Pearce (1976) argues, no

method has been entirely successful in deriving economic values for the predominant environmental externalities.

3. Techniques for environmental valuation

A number of methods and techniques have been developed in an attempt to secure money measures for diverse non-priced environmental attributes, such as goods, assets and amenities. The existing approaches search for distinct dimensions for environmental evaluation into economic analyses, consistently with the underlying economic theory and, when it is the case, with actual market behaviour.

Environmental aspects can be valued monetarily through distinct techniques, each of which has its own characteristics, requirements, advantages and disadvantages. It is important to determine the techniques which are able to carry out the type of valuation in question. The success of valuation depends a great deal on the choice of the technique, which should consider its best suitability for specific applications[1].

The literature reveals quite a disagreement of concepts, classifications and terminologies. This chapter presents a review of the general techniques particularly useful for deriving values and costs related to the predominant environmental effects produced by the provision of road transport.

3.1. Damage costs

Any productive system can potentially impose damage for a segment of society or even for the entire humanity. Hence, any damage is directly or indirectly associated to costs, which may be used as a proxy measure of economic valuation. Transport produces a range of direct costs from pollutant exhausts, and indirect costs from loss of amenity due to noise levels exposure. There are six main groups of environmental damage costs incurred from traffic:

- *Material damage*

Environmental degradation may harm materials and goods, producing expenses such as cleaning up, washing, repainting, eliminating corrosion, restoration, conservation of building facades and replacement of damaged material. The derivation of damage cost for most of such effects is

straightforward, associated to the prices of products in the market. However, an estimation of the period for which cleaning or replacement of materials is required may not be trivial.

• *Accidents*

Road traffic accidents can cause from the lightest to the most severe injuries. The monetary costs of injuries derive from patient treatment, hospitalisation, medicines, loss of productivity due to restricted activity, personal morbidity, etc. Mortality may also occur in case of accidents, in which case the value of lives lost shall be derived. Road traffic accidents cause further damage cost, the estimation of which requires an evaluation of the expenses from repairing vehicles, transport equipment and other urban facilities damaged. Accidents may also be induced from reduction of visibility due to the presence of particulate matter on the atmosphere.

• *Health damage*

Polluting activities can produce damage on health. The expenses incurred by health damage are originated from: patient treatment, hospitalisation, utilization of Health Service funds, drugs or medicines, service of specialists, nursing care and sickness benefit. Costs may also originate from earnings and labour productivity that are forgone or declined due to absenteeism from work. These costs represent the extent to which a change in environmental quality affects human health, and as consequence, actual production or production capability. The valuation of reduction in productivity can be derived from the estimation of the number of days lost from work because of pollution-induced health harms multiplied by the average wage rate. In the extreme situation, costs can be derived from premature death caused by exposure to air pollution.

• *Living environment*

The presence of polluants in the atmosphere can cause loss of satisfaction and welfare. This inconvenience is particularly felt in relation to particulate matter, for it affects aesthetics reducing visibility and producing odour.

- ***Fauna and flora***

As air pollution (principally through acid rains containing NO_x, SO_2, HC and O_3) may diminish the growth of plants, this decreases the yield of agricultural products and damages forests. The effects of pollutants on animals is very little known.

- ***Global effects***

The concentration of CO_2 in the atmosphere has proved to provoke an increase on the average global temperature. As a result, the greenhouse effect is expected, with vast and still uncertain consequences on the world ecosystem.

The damage cost technique makes straightforward use of market prices, where all incurred costs are accounted by the "enumeration-and-valuation" methodology. Thus, the monetary assessment of damage costs requires a series of estimations, as follows:

- the amount of physical degradation and subjective annoyance caused by the particular activity being looked at – in this case, transport. Measurements or predictions are required for quantifying environmental impacts[2].
- the quantity of material (building facades and infrastructure facilities), size of population (humans, plants and animals) or environmental resources exposed to different levels of impacts.
- the extent to which damage affects people, health, materials, plants, animals and resources. This can be derived from damage functions or dose-response relationships between exposure to impact and resulting effect.
- the money value associated to each unit of degradation and further expenditures incurred. The environmental costs can be devised by summing up in monetary terms all effects that contribute to the damage.

This technique tends to provide underestimated results, as some elements which magnitudes are unknown may be missing in the calculation. While there are negative externalities perfectly identifiable, others less tangible/perceived or more subjective may provide great difficulty for detection and quantification. Thus, regarding

that there is a substantial complexity in quantifying the impacts and estimating the total environmental damage, one can argue that there is much littler prospect for evaluating the financial marginal costs of the environmental degradation produced.

A wide amount of economic data based on current market prices and an estimation of the quantity of material and people at risk are required for the application of this technique. Data may be required from diverse fields, for this technique has an inter-disciplinary feature. Besides, the number and the nature of activities, people, goods and other factors involved are so great that estimates may become subject to a high degree of uncertainty. Damage from traffic air pollution can be quite difficult to be detached from any other possible source. Dose-response relationships are neither simple or fully understood. They have not yet been derived for most environmental effects, as there are still considerable gaps in knowledge of adverse effects of diverse exposure levels of pollution, mainly on human health and material deterioration. The cost estimation is usually produced for the society as a whole.

This technique may also depend on a number of assumptions about maintenance. Repairing prices may vary immensely, according to the quality of materials and labour employed. Further assumptions have to be made about the period for which polluting activities have contributed to damage costs to human health, plants, animals and materials, as it is most likely to be felt over a number of years, due to the gradual and cumulative effect of pollution. Current and past environmental degradation are also an inheritance to the next generations. This includes the additional complexity to the problem of how to evaluate the cost produced by an effect that will take place in the future and which consequences are not known enough about (Hansson, 1991). Estimating costs related to irreversible effects acquires a further degree of complexity.

Therefore, the main limitation of monetising environmental damage originates from the large number of data and simplifying assumptions required. If the difficulties on valuing the costs of the goods or assets above mentioned could be overcame,

this would be far the most comprehensive and absolute within the existing techniques for environmental degradation.

3.2. Avoidance costs

Avoidance or control expenditures refer to the cost of various preventive or corrective measures taken to eliminate or mitigate environmental externalities. The need for such expenditures indicate the minimum valuation of satisfaction or benefit gained from environmental improvements (more in Starkie and Johnson, 1975). Examples of corrective expenses include the implantation and maintenance of noise barriers and double glassing to reduce indoors noise levels, and catalytic converters to reduce pollutant emissions. This technique relies upon the available technology.

The actual value of damage or public preference can be higher or lower than that provided by this technique. For instance, the benefit or satisfaction from the implementation of avoidance devices may be judged to exceed the costs incurred. Besides, the extent to which these costs are actually accepted by individuals is difficult to be estimated (World Bank, 1991).

Although this approach may be applied purely on theoretical basis, its practical viability is limited to cases where households spend money to offset environemental hazards. Thus, the total avoidance cost would fail to capture cost where remedial measures will not be implemented either for technical, political or mainly personal reasons (in case individuals are not willing to acquire such devices).

3.3. Compensation costs

The compensatory costs represent the set of expenditures from measures necessary to compensate monetarily the harm caused by an imposition or simply by an increase of environmental degradation. This principle is most commonly applied on assessments of road construction, from which properties lose amenity or have to be demolished. The application of this technique usually provides information only on a small segment of the population.

3.4. Surrogate market

Individuals express daily several preferences for or against goods or services to be received in exchange of money. These preferences influence behaviour

and originate decisions, which are based on market prices.

The consequences of changes on environmental quality can partly be expressed in the market values, through an approximate value of a change on the potential welfare (Pearce, Markandya and Barbier, 1989). Surrogate pricing methods use the information revealed by actual market transactions, on the purchasing price and demand of goods, assets or services, to infer indirectly the money value of environmental attributes which do not have market prices. Although this approach is based on the realms of economic theory, its primarily conceptual feature tends to provide difficult practical application. The main techniques based on the surrogate market approach and related to the impacts of transport are *property prices* and *travel costs*:

3.4.1. Property prices

There are several factors influencing house prices. The disbenefits of environmental degradation can be felt on housing market, through the marginal reduction in land, rent or property values it provokes. The property value technique is conceptually based on the hedonic price theory, in which the monetary value associated to the environmental conditions can be derived from the demand for housing[3].

An academic illustration for this technique is the hypothetical situation of two properties identical in all aspects, except in relation to a specific environmental characteristic. The difference of prices between them indicates the valuation of such environmental asset. Such an ideal situation, however, is unrealistic for most practical studies, in which properties present an array of features composing their market price. Thus, this method aims to estimate the part of the difference in house prices which is separately associated with environmental quality differences at distinct situations.

This technique applies multiple regression in which data are taken either on a small number of properties over a period of time (time series) or on a larger number at a point in time (cross section). Best results are obtained when properties are in the same geographic area, with similar household, accessibility and neighbourhood characteristic.

Although technically feasible, the main deficiency of

this method lies in its very conception. Since house market prices reflect a very large range of attributes, it is extremely difficult to isolate the influence of a specific impact on prices. This method is not suitable for long term analyses due to the likelihood of further factors affecting the property market take place. The consideration of more than one environemental attribute on the property value is even more complex. This technique is applicable only to impacts which are likely to be capitalised into property values. Thus, it is most appropriate to reflect the environemental losses from the implantation of projects, and not quite suitable to value, for instance, the marginal noise nuisance caused by an increase on traffic flows.

Another great disadvantage of this approach is that, in practise, the necessary data on house price changes are almost impossible to be regularly obtained. It depends on an adequate sample of market transactions, but usually only a very small percentage of the total housing stock is exchanged at the same period. This technique would achieve best results if an extensive degree of mobility existed, because in reality few households move for an increase in environmental degradation. Besides, this method does not assess the nuisance suffered by non-property owners, visitors, casuals and local workers. In a rather radical statement, Pearce, Edwards and Harris (1979) claim that this method almost certainly is not capable to estimate environmental valuations.

3.4.2. Travel costs

This method assumes that the costs incurred on travelling (including the value of time) can be taken as a proxy for the monetary value of an amenity. It relies on the observed behaviour of people, by assessing the extent to which travellers are willing to trade their journey length or time (accounting for increasing expenses), in order to avoid stress and bothering, or to gain satisfaction from a more attractive and pleasant route (Rendel Planning and Environmental Appraisal Group, 1992).

This method does not require extensive deal of information, but surveys on travel time and expenses. On the other hand, its applicability field is rather restricted. Besides, the environmental influence is

difficult to be captured from multi-purpose trips.

3.5. Preference surveys

Experimental approaches for monetary valuation of environmental goods or amenities simulate a market by placing respondents in a position in which they are asked to express their individual subjective short-term preferences of economically perceived changes in their welfare, utility or satisfaction. Preference surveys are, therefore, means of measuring public preference on non-marketed goods. These techniques are based on the principle that, if people are willing to pay a certain amount for the protection or improvement of a non-priced good or asset, then it is supposed to be worth at least the amount given.

Interview techniques provide great versatility, because they can be applied to a range of environmental attributes, including preferences, subjective losses or gains. Attributes can be directly and separately addressed. Besides, these surveys can be applied to situations where values are not captured by traditional benefit measuares. The Department of Transport (1992) considers these techniques as *the greatest early scope for monetary valuation.* The monetary values for the predominant external effects from road traffic can be estimated through distinct experimental survey techniques: *contingent valuation, stated preferences* and *transfer prices.*

3.5.1. Contingent valuation

Contingent valuation methods (CVM) or revealed preferences techniques are derived from a social sample interview which assesses the maximum *willingness to pay* (WTP) for preventing environmental deterioration, improving or maintaining acceptable conditions, or mitigating certain effects down to a certain aimed level. Alternatively, it can be based on the *willingness to accept* (WTA) compensation for a loss at the very least amount. Bids for improvement of the environment have proved to be lower than those to prevent further deterioration. As expected, yet contrary to the economic theory which suppose them equal, this can be explained for the fact that individuals tend to dislike more the idea of losing an attribute already owned than acquiring

further satisfaction. On the comparison of WTP and WTA estimates, measures of the last were consistently found to be 3 to 5 times larger than the former (Cummings et al., 1986). This suggests that WTA respondents tend to overestimate their demands whereas WTP respondents would be inclined to underestimate their preferences.

The willingness to pay criterion was one of the first means used for valuing time savings, especially in the United States. It is indeed consistent with the general theory of market economics and it is a clear market test of user preference (Howe, 1971). This technique is comparable to psychological tests, and it still is in many ways the most direct and simple method to understand. It is potentially capable of valuing directly a broad range of environmental effects, goods or assets, including impacts non-readily identifiable and which have no natural unit of measurement, such as annoyance, disturbance, risk, fear and other psychologic effects. Thus, CVM provide an extraordinary freedom for environmental valuation and do not depend on extensive data base, like most of the previous techniques presented. Several variations of this method have been developed (Dixon et al., 1988).

As stated by Langdon (1978), *"monetary evaluation by direct questioning is feasible in practice, yields actual results and produce values not inconsistent with those obtained by means of different methods"*. Cummings et al. (1986) support that carefully constructed, CVM give meaningful values for environmental goods with an accuracy of + 50%. Such an approximation is considered reasonable for the nature of the experiment and magnitude of the values involved. Bishop and Heberlein (1986) state that CVM are not likely to produce results more accurate than + 50% of the measured figures. Nevertheless, they acknowledge that *while CVM appear to be biased even under the best of circumstances, the degree of bias does not appear to be sufficiently high to rule out use of the results in public decision-making.* It is yet asserted that CVM have shown itself sufficiently promising to warrant a major research effort, mainly on experimental techniques. Mitchell and Carson (1989) support that CVM are the most powerful and versatile tool for valuing

non-market goods and properly carried out its findings are meaningful. Therefore, CVM are potentially capable to provide important information about the environmental effects produced by transportation.

Despite the revealing promise of survey methods, they might not capture the full and precise values and preferences of non-marketed effects. In many cases, only a broad range of the plausible valuation may be estimated. Besides, CVM are based on the estimation of disutility of illness to individuals and do not reflect social costs. For CVM are vulnerable to misuse and biases, there are numerous practical and theoretical issues which need to be carefully addressed on their design and application, in order to reduce the serious threat to CVM's validity. A large part of the literature on CVM is taken up with discussion about their accuracy problems.

3.5.2. Stated preferences

Survey techniques can also assess individual valuation through statements of preference. In this variation of demand revealing methods, the respondent is provided with a base level of an environmental good and is offered an alternative in which the environmental good is increased, but at a price which is varied until the respondent sees no advantage in an alternative over the other (Dixon et al., 1988). Questions can be made directly about the state of preference among a number of hypothesized choice scenarios, on the basis of multiple combination of differing levels of environmental attributes, time and money inherent to each alternative. Alternatives are ranked or chosen through the observation, comparison of options and making trade-offs of monetary values placed on the non-monetary attributes. Fowkes (1991) calls 'boundary values' those which reflect a trade-off between two alternatives at which respondents are just indifferent about their relative valuations.

This technique has been used in a variety of speculative applications. Based on previous experience, Hopkinson et al. (1990) concluded that people find it easier to order their preferences than state directly how much they would be willing to pay for environmental goods. However, this technique is strongly dependent upon the choice set of scenarios available to individual

respondents (Bates and Roberts, 1983), and the structured alternatives may diverge from real choices.

3.5.3. Transfer prices

This survey method is based on the amount by which the cost of one option would have to be varied to equalise its overall attractiveness or disutilities towards that of another predefined alternative (Gunn, 1984). Respondent are asked to assess the indifference point in the choice, through the amount that the cost of a preferred option would have to rise in order to induce them to switch to a rejected alternative (MVA, 1987 and Broom et al., 1983). In fact, this approach is restricted to a comparison with the expectation formed on the basis of revealed preferences.

4. Economic instruments on environmental damaging activities

A great deal of human activities imply that one good is transformed into another. This process very often generates damage. Environmental damage involves complex social costs, which direct or indirectly have been or will have to be paid by someone.

According to the polluter-pays principle, environmental charge or cost-responsibility, the cost of environmental preventive and corrective measures should proportionally be inserted in the cost that the production and consumption of goods and services impose on society. Thus, the polluting activity would pay for all the resources it consumes, like any other economic activity in the market, plus the marginal damage generated. Monetary valuation for negative externalities allows a proper setting of economic instruments on environmental damage, as to control environmental quality.

The existing economic instruments for controlling environmental pollution are taxes, charges or subsides. Subsides are financial assistance for activities that provide incentive to ecological preservation. Contrarily, taxes and charges are imposed upon polluting activities[4], which appropriate level should equal to the monetary value related to the extra damage generated. Taxation upon polluting activities can be conceived as an economic

instrument for preventing misuse of scarce environmental resources, or alternatively as suggested by Baumol and Oates (1971), as the price for the private use of social resources.

Charges should be proportional to the level of degradation. The charge level must be settled high enough to provide a sufficient incentive for polluters to reduce their discharges down as to achieve a desired ambient quality within a specified time, but not so high as to increase the activity costs up to undesirable levels. This can be settled by trial and error, firstly setting a charge and observe its effects, and then adjust it up or down until the ambient quality reaches the desired goal (Anderson et al., 1977). Measures to reduce environmental impacts must be economically more advantageous than the payment of charges. In this respect, instruments should not sell pollution rights, otherwise, contrarily to the implicit objectives, the polluter may prefer to pay and continue polluting[5].

The obligation to pay for the environmental harm produced provides an incentive not to cause that harm (Anderson et al., 1977). Firms will choose to pay the charge or invest in new and less environmentally damaging methods of production. The development of cleaner technologies would be promoted, as demand for less polluting processes increases. The public should be informed of the magnitude of pollution caused by production and how much extra is incurred on anti-pollution costs.

Evidences presented by Pearce, Markandya and Barbier (1989) suggest that market-based approaches to pollution control can be highly cost-effective. The main aim of this principle is to alter behaviour, but it can also raise revenue (Pearce, 1989). The revenues raised may be reverted into funds for preventing further environmental degradation or used where they are best needed, provide they are used to achieve the objectives for which the charges were formed.

In relation to transportation, the price actually paid for dislocations does not yet reflect such inherent costs. In this sense, the transport policy has to decide whether the transport users themselves should pay for the external social costs incurred from the use of environmental resources, or if the whole society

should eventually shoulder them. The compensation for the cost, damage or disutility generated by road traffic pollution can be imposed through measures to prevent or discourage car usage, such as road user charges, road pricing, fuel taxation or subsided fares. The charges on environmental impacts could help reducing vehicle miles travelled and encourage the use of more environmental-friendly modes of travel. Such instruments should reflect not only the pollution costs related to the manageable effects but also the implicit costs of irreversible ones, like the greenhouse effect.

In the U.K. the differential between the tax on leaded and unleaded petrol is an example of a market-based instrument, where the polluter pays more for harmful emissions. The result of such a measure, introduced in 1987, is the rise on the sales of unleaded petrol to about 35% in three years (Secretary of State for the Environment et al., 1990) and the drastic reduction of lead concentrations throughout the country.

In Sweden, economic instruments were introduced into its environmental policy in 1988. Such instruments attribute a social marginal responsibility charges for road and rail air pollutant emissions (Hansson, 1991). Another example of economic instruments on transportation can be found in Germany, where tax reductions are given for catalyst equipped vehicles and tax leaded petrol has been differentially rising since 1989 (Blum and Rottengatter, 1990).

Despite the very sensible theoretical grounds of economic instruments on environmental damage, there are several practical difficulties for implementing such a principle. The incorporation of environmental costs into polluting activities tend to make them more expensive. Thus, the consumer would end up paying for it and not those who are actually producing polluting. Furthermore, several economic and social consequences are likely to raise, which must be outweighed in the balance.

5. The valuation of specific environmental effects of traffic

The idea of attaching monetary values to environmental damage is relatively recent and the world experience in doing so is still limited, particularly in relation to traffic-induced

impacts. Nevertheless, money estimates have been derived in many situations. Data on total annual pollution damage and on the benefits of pollution control are widely available in the literature, particularly related to the OECD countries[6]. Results from the practical experience of environmental monetary valuation in some developed nations is extensively described elsewhere[7]. The efforts of Germany and the United States are noticeable, for these countries have given outstanding contribution to the state-of-the-art. In Scandinavia, a modest number of studies have resulted on a precious experience.

Environmental impacts are disparate in nature and several effects can be originated from each impact. The main impacts of traffic are air pollution and noise, from which the predominant effects produced are noise nuisance, damage to health, deterioration of the living environment and damage to materials. Each of these effects may be valued through different monetary techniques, according to their characteristics, suitability and data required. Table 5.1 shows the appropriacy of techniques to value each effect.

Table 5.1: Suitability of techniques to value environmental effects

Technique	Noise	Air pollution		
	Noise nuisance	Damage to Health	Deterioration of environment	Damage to materials
Damage costs	no	yes	no	yes
Avoidance costs	limited	no	limited	no
Compensation costs	limited	limited	no	no
Property prices	yes	no	yes	no
Contingent valuation	yes	yes	yes	no

This section is focused on the valuation of the local effects of traffic within a limited urban network, which directly or indirectly represent eventual costs. Thus, there is a range of

regional[8] and global effects[9] which are not included on the scope of this section, although their relevance in transport planning is largely acknowledged.

Some effects can be fully valued through one particular technique, but no general technique is capable to reflect a comprehensive valuation of all the diverse degradation effects raised, at least on its best efficiency. In this case, complementary valuation may be recommended, where distinct techniques are combined in order to estimate the total valuation[10]. Whenever possible, results should be compared with others provided by a distinct technique, in order to ascertain the consistency and accuracy of valuation. However, this would require a significant increase on the overall application cost.

5.1. Noise nuisance

Nuisance, annoyance, disturbance or bother are overwhelming effects from road traffic noise, distinctly perceived by individuals in residential areas[11]. Noise nuisance is physiologically harmless within a large extent. However, environmental hazards may develop through symptoms such as effects on hearing and communication, headache, increased blood pressure, sleep disturbance and insomnia. Although rare, serious impairment in human well-being, such as mental and psysical health problems and damage to auditory organs, may also occur.

5.1.1. Avoidance costs technique

A simple approach to value noise nuisance is through the costs of sound insulating buildings (double glassing) or mitigation noise propagation (noise barriers). Thus, insulation costs can be conceived as the monetary values necessary to provide the benefit of reducing noise nuisance (Starkie and Johnson, 1975). It is difficult to estimate a standard insulation cost, as it depends upon a number of variables, namely: type and size of the windows, material employed (aluminium, PVC, etc.) and type of insulation (simple secondary glassing panels or replacement of the window). Hence, double glassing tends to raise property values and could reduce the losses suffered from noise nuisance.

5.1.2. Compensation costs technique

In specific cases, the value of

the inconvenience caused by noise can also be derived from the amount of compensation due, for instance, to workers who have become hard of hearing due to noise at workplace or to residents who have lost amenity due to indoor traffic noise nuisance. The sum of money required to make residents as satisfied after the imposition of a noise nuisance as they were before has been assessed by Plowden and Sinnott (1977).

5.1.3. Property prices technique

Far more extensive experience has been gained by valuing noise nuisance through the capital loss from a fall in the property prices, as a consequence of a decrease in environmental quality. The property value approach on nuisance has mostly been applied to the effects of aircraft noise (Walters, 1975; Nelson, 1980; O'Byrne et al., 1985). It was also employed in the most comprehensive and sophisticated attempt to attribute monetary values to environmental aspects in the U.K. (Commission on the Third London Airport, 1970 and 1971), when appraising the economic costs and overall benefits from the implementation of the third airport. Noise nuisance produced by aircrafts is not equivalent to that by traffic. In fact, evidences on the literature suggest the first to be way more intense. This is due to the characteristics of intermittence and high frequency of aircraft noise emissions. Valuation of road traffic nuisance, although a little more scarce, has also been consistently derived (Pearce, 1977; Nelson, 1982; Romer and Pommerehne, 1992; Navrud and Strand, 1992; Jeanrenaud et al., 1993).

5.1.4. Contingent valuation technique

As long as the effects of nuisance are clearly perceptible, CVM are appropriate to assess monetarily noise nuisance from traffic. They are sensitive enough to catch up such sort of subjective and marginal disturbance. A good deal of research has been done on the value of peace and quiet in monetary terms (Starkie and Johnson, 1975; Langdon, 1978; Romer and Pommerehne, 1992; Baughan and Haddart, 1992; Jeanrenaud et al., 1993).

5.2. Damage to health

As far as the impacts produced by road traffic are concerned, health problems are

principally derived from air pollution. Health damage is one of the most important elements of total traffic environmental damage cost, principally in populated areas. The chronic diseases caused by air pollution may contribute to both higher morbidity and mortality rate. Death and sickness depend on how exposure for a certain period of time to pollutant concentrations is connected with health harm. A 1970 study reported in Danish Ministry of Energy (1991) estimates that 50% of all respiratory diseases are associated with air pollution.

The mobile pollution sources can cause or contribute to a number of respiratory and cardiovascular diseases, but the extent to which this happens is widely uncertain. The main respiratory diseases are lung cancer, pneumonia, tuberculosis, asthma, bronchitis and emphysema, whereas the main cardiovascular are headaches, cough, cold, sore throat and eye symptoms. Further psychological effects, such as pain, suffering and emotional distress may also occur.

Most of the compounds in exhaust gases are probable to increase the incidence of cancer. Carbon monoxide diminishes the oxygen supply to the respiratory system. Ozone[12] and nitrogen dioxide reduce respiratory performance. The combined effect of more than one pollutant acting simultaneously may be considerably more harmful than the simple addition of their isolate effects.

5.2.1. Damage costs technique

The health damage costs imposed on society in a certain place and time period are associated with the monetary consequences of pollution related diseases. Damage cost is the most comprehensive and detailed technique to assess the health damage caused by air pollution. Empirical data are required to produce damage functions relating a particular marginal health effect of air pollution to measures of air quality, which are indicators of actual exposure. Current observations of ambient quality and exposure to air pollution is not an adequate indicator of actual level of degenerative diseases or death, as air pollution usually provokes long term and cumulative effects. For example, cancer is caused by exposure to carcinogenic substances over a prolonged period of time and, according to

Kneese (1984), it may occur as much as two decades after exposure. Therefore, estimates on the number of diseases and deaths due to air pollution may require extensive historic data collection.

The main problem with estimating health damage is the inexistence of information on the increase on severity of existing diseases and on non-reported incidence of illness. Epidemiological studies only investigate the health effects from normal living exposures to pollution, so they povide difficulty to distinguish the contribution of diverse sources to health problems. Clinical studies can only account for physical or psychological effects, as it is not possible to expose people deliberately to pollutants over long periods of time or at concentrations that are likely to result in severe or harmful effects (more details on this subject can be found in Horowitz, 1982). Horowitz (1982) reports some dose-response relations between concentrations of diverse pollutants and clinical symptoms.

Empirical work in this area is limited, and as supported by Pearce and Markandya (1989), sophisticated data required are very rarely available outside the United States. Some estimates have been done on the overall costs related to health damage and the figures are alarming (Rice, 1966; Cooper and Rice, 1976; Danish Ministry of Energy, 1991).

Respiratory cancer can be directly related to the incidence of air pollution and estimates have been made on the number of years lost per patient with such a disease. As no concrete evidence has been found in the literature about life years lost due to air pollution-induced cardiovascular conditions, limiting health damage to respiratory cancer will certainly underestimate results. Illness and death from air pollution can be caused by diverse types of emissions. Smoke habits and proximity to industries should be considered when evaluating the health effects of pollution.

Air pollution has been reported as responsible for restricting activity, and therefore reducing productivity. In the case of death, the monetary loss can be estimated from the net value of the expected lifetime earnings. The estimation of earning losses through this technique strictly evaluates the sickness effects on the productive population. Thus, the health effects on non-productive people, such as

elderly, housewives and children, who are usually the most strongly affected, are not accounted.

The economic burden of health damage on society is estimated through the damage costs technique by accounting the incurred costs on hospitalisation, health care, mortality, morbidity and productivity reduction:

- ***Hospitalisation and health care costs***

There is enough evidence that air pollution can cause or aggravate physical and psychological impairment to such an extent that the person exposed may need to seek medical attention and/or consume medical services. The costs incurred include hospital room rent, consultation, medication, surgical procedures, laboratory and radiological examinations. Amongst the literature referring to the evaluation of such costs are: Silverman (1973), Cooper and Rice (1976), Bhagia and Stoevener (1978) and Shechter (1992).

- ***Mortality costs***

Air pollution has proved to be associated to mortality rate (Lave and Seskin, 1977; Hartunian et al., 1980; Schwing et al., 1980 and Turner and Bateman, 1990). Several researches have derived valuation for human life, for instance: Cooper and Rice (1976), National Academy of Sciences (1974), Kneese (1984), Pearce, Markandya and Barbier (1989), HM Treasury (1991) and Danish Ministry of Energy (1991). The valuation of life from these studies ranges significatively, mainly because different theoretical grounds and assumptions underlie them.

- ***Productivity reduction costs***

Evidence has also been found on the relationship between ambient levels of air pollution and various measures of morbidity, such as working days lost (absence from work) and restricted activity days (days affected by ill-health). Diverse figures can be found in Cooper and Rice (1976), Lave and Seskin (1977), Ostro (1983) and Kneese (1984).

5.2.2. Compensation costs technique

The amount of compensation demanded for health losses as a result of exposure to air pollution

can provide valuation for health damage. Damage to health and value of life can also be estimated through compensating wages in high accident or death risk jobs. The costs from pain and suffering associated with respiratory injuries, as imposed by air pollution, have been evaluated by the National Academy of Sciences (1974).

5.2.3. Contingent valuation technique

The valuation of health damage can be estimated through the amount people are willing to pay in order to avoid all the costs (such as those dealt with the damage cost technique) and losses associated with disutility of illnesses (such as for pain and suffering) from getting sick, or for reduced mortality risks. The valuation of averted morbidity costs through contingent valuation depends on the extent to which respondents properly realise all the health effects of air pollution and are able to value them. A few researches on how people value their health conditions have been carried out, mainly in the United States (Loehman et al., 1979; Chestnut and Violette, 1984 and Gerking and Stanley, 1986). Value for life can also be derived from life insurance premia, like the insurance of marked priced goods, which is the amount insurance companies are willing to pay for the risk of someone's death.

5.3. Deterioration of the living environment

Air pollution may dirty the atmosphere, produce odour, reduce visibility (and safety as a consequence) and affect a diversity of aesthetic and public factors. All these effects contribute for the deterioration of the living environment, causing loss of amenity, well-being, enjoyment or satisfaction. Different methods have been applied for estimating values to the living environment.

5.3.1. Avoidance costs technique

This technique assesses the cost incurred from the implementation of catalytic converters in private vehicles. The valuation of avoidance costs has been derived, for instance, by the Danish Ministry of Energy (1991), whereas estimates on the purchase of catalysts can be found in Ball (1984) and Schwing et al. (1980). The efficiency of catalysts is reported in Pearce and Davies (1990). The introduction of

catalysts is a slow business and it is not likely to be attained in less than a considerable number of years, since yearly substitution of vehicles covers only a small percentage of the total fleet.

5.3.2. Property prices technique

The presence of air pollutants in the atmosphere can also induce property depreciation. Several studies have found significant correlation between fall in property values and increase air pollution levels in urban areas: Freeman (1979), Romer and Pommerehne (1992), Schulze, d'Arge and Brookshire (1981), Brookshire et al. (1982), Chestnut and Violette (1984) and Shechter (1992).

5.3.3. Contingent valuation technique

Further and more recent attempts to assign economic values for deterioration of the living environment due to air pollution have been made through CVM: Dorfman (1977), National Academy of Sciences (1974), Schulze, d'Arge and Brookshire (1981), Brookshire et al. (1982), Chestnut and Violette (1984), Schechter, Kim and Golan (1989), Schechter (1992), Navrud (1991) and Navrud and Strand (1992).

5.4. Damage to materials

The damage cost technique is the most suitable procedure to estimate in monetary terms the harm caused by air pollution to materials. Road traffic air pollution can cause harm to numerous materials, but those in closer contact with exhaust emissions are likely to suffer most from the damage[13]. The principal pollutant compounds on damage to materials are sulphur, particulate matter, oxidants and nitrogen oxides. Pollutant deposition provokes deterioration of building facades and other materials, mainly through the erosion of surface coatings and corrosion of metals. Besides, soiling due to particulate deposition is aesthetically unappealing. Diesel emissions are the principal responsible for soiling effects in urban areas.

5.4.1. Damage costs technique

The economic costs from material damage can reach considerable amounts (National Academy of Sciences, 1974). Empirical studies have concentrated on the effect of sulphur compounds and particulate matter, and as suggested by Winpenny (1991), damage on only part of the

spectrum of material at risk has so far been researched. Assessment of material damage is complex due to the threshold levels of deposition, before which corrosion may be neglected and after which it may be accelerated. Dose-response relationships have not been sufficiently developed yet. Very little practical research has been found in the literature on the costs of material damage. Even fewer studies have focused material damage on a disagregate level. The existing studies have concentrated either on the effects of specific materials, historical buildings and monuments or roadside building facades: Michelson and Tourin (1966), Ball (1984) and Jeanrenaud et al. (1993).

6. Conclusions

The techniques for estimating monetary values to environmental attributes still remain at an early stage of technical development and public acceptance. Existing techniques are subject to great deficiencies and difficulties of application. They inevitably rely on large number of assumptions, hypothetical statements, or complex, extensive and expensive data requirements. As a result, even the best technique and data base available are unlikely to generate accurate and reliable estimates. Yet, it is difficult to evaluate how successful the existing attempts have been to attribute value to environmental aspects.

Nevertheless, monetary techniques are the only existing devices to translate environmental damage or benefit into money terms. Monetary valuation is considered an advance for the most sophisticated and comprehensive cost-benefit analyses, for providing basis for environmental conservation. Although better accuracy would be desirable, order-of-magnitude estimates may be valuable for policy decisions in many situations, and preferable than no information at all. Whether environmental valuation is considered, it is inevitable to accept a substantial degree of uncertaintly, which is characteristic of the various shady frontiers of knowledge involved. Monetary valuation should produce indicative rather than absolute outputs. Therefore, results must be treated with caution and scepticism.

Many attempts have been made for deriving a proper monetary value, price or cost for

environmental attributes. Some experience has been achieved particularly on the valuation of adverse environmental effects caused by the provision of transport. Strong evidences suggest that the valuations of external costs of transport actually represent considerable monetary sums.

Progress in improving results of monetary valuation for environmental attributes is possible and should be continually pursued, with due recognition of the intrinsic uncertainty involved. Considering that some effects which a couple of decades ago were classified as intangible, now are estimated monetarily, if development continues, other remaining difficulties are expected to be sorted out within the near future. For this, considerable expertise and research experience ought to be built up until environmental valuation is better accomplished. More information, time and resources should be made available for encouraging researches to improve the performance of existing techniques or develop new and more reliable methods. More direct and accurate evidences must be developed on the dose-response relationships between changes in environmental quality and the various consequences in health, damage, productivity, nuisance and well-being. More profound research design should be pursued with parallel elaboration of stronger links between empirical work and economic theory. As research in the environment valuation progresses and improved knowledge of environmental costs is revealed current valuations may be dated to more realistic levels. Finally, society should be prepared to accept the devices conceived to attribute values into environmental degradation.

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