Order Number: T8080-00-1018

INTERNALIZING THE SOCIAL COSTS OF THE TRANSPORTATION SECTOR

Prepared For

TRANSPORT CANADA

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December, 2000

RESEARCH AND TRAFFIC GROUP

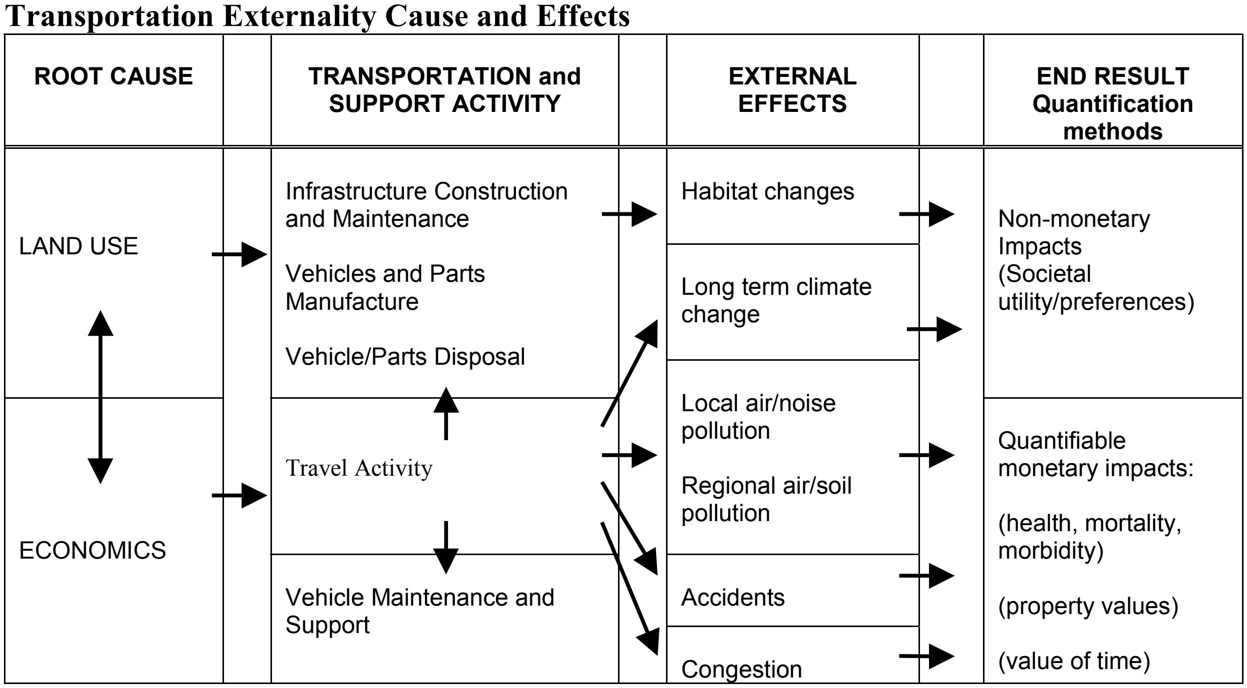
Executive Summary

As a first step in evaluating the internalization of environmental costs, Transport Canada sought a review of the literature of social cost estimates—including environmental costs—for all transportation modes, plus an account of various jurisdictions' experiences as they implemented policies designed to internalize social costs. We understand that Transport Canada plans to use this review as a springboard for stakeholder consultations, which will be aimed designing a strategy that maps the path to identifying and resolving conceptual, policy and practical impediments to implementing social cost internalization in Canada.

CONCEPTS

One of the more succinct definitions attributed to DeSerpa is: "*an externality is a relevant cost or benefit that individuals fail to consider when making rational decisions*". Externalities are generally recognized to be a major problem within the transportation sector. Transportation activity imposes external impacts on present and future generations. These impacts are illustrated in the cause-effect chart below.

Transportation Externality Cause and Effects



Since the market provides no incentive for individuals to take external costs into account when making transportation decisions, resources may be misallocated. Internalization measures bring the costs or benefits back into the decision-maker's evaluation framework, thereby making them internal to market-based transactions.

Externality pricing is one internalization measure.[#] In an ideal regime, external social costs would be added to the price of the activity that produced them, such that incremental activity would only take place if total marginal social benefits outweighed total marginal social costs. However, the theory of optimal taxation (in which taxes are designed to acquaint transport users with the full social costs of their activities) is developed within the framework of perfect markets. In practice, policy makers consider many other factors when they determine whether regulation or economic instruments are more cost effective in dealing with specific externalities associated with specific activities/ products. Discussion of economic instruments focus on methods of improving the tax system to better align usage costs with external effects, rather than on determining the optimal tax.

Equity issues include both horizontal and vertical equity. The *horizontal equity* concept addresses the question whether those who benefit from transportation infrastructure pay appropriately for it. The vertical *equity* concept examines the question whether various segments of society such as the poor, aged or handicapped receive adequate benefits from public expenditures and investments in transportation. A Transportation Research Board Committee for Study of Public Policy for Surface Freight Transportation [TRB, 1996] cites horizontal equity issues as one area of justification for user pay principles, but considers that vertical equity issues are different in freight transportation than other sectors.

Economists are in agreement that short-run marginal social costs (SMSC) provide the correct conceptual basis for efficient pricing. In other words, transport users should bear all the additional costs that their activities impose on the economy.[*] Short-run costs vary by vehicle, time, route and location, and also according to the weather and season. While SMSC provide the appropriate conceptual benchmark, it may not be feasible to calculate short-run marginal costs. Moreover, taxes or charges designed to close the gap between private and social costs vary between regions and change from one period to the next.

EXTERNAL COSTS ESTIMATIONS

Whether economic instruments or regulations are used, guidance in determining the appropriate magnitude of intervention requires the measurement of the total social cost.

The economic efficiency argument for the internalization of social costs is tied to having total costs within the decision makers reference frame. In order for this to happen, the internal costs and revenues also need to be allocated on the basis of their costs and benefits. Thus, cost allocation studies become a component of social costing in the transport sector.

* While road users take account of the marginal costs they incur through additional driving time and expense, they do not take account of the costs they impose on other drivers and on local residents.

The problems of social cost measurement are significant. While the identification and allocation of the private and public costs can involve a substantive data and analytic exercise, these costs have a monetary basis to work from. Measurement of the external costs of non-market goods involves additional, complex analytic steps. The evaluation of policy instruments to mitigate external costs requires the development of functional relationships where historic experience is limited. Evaluations often must be based on supposition of data and/or transfers of experience from other jurisdictions.

The quality and originality of analyses/data is lacking in many studies, particularly for the freight modes. Our discussion of methodologies draws heavily from Delucchi's series of reports, and from Environment Canada's AQVM3.0 User Guide. We also reference the methods used in the underlying studies of the ECMT [1998] discussion of internalization. The order of magnitude of the final estimates from Delucchi for the U.S. and from the ECMT for an average of 17 European countries is illustrated below.

Externality Estimates as a Portion of GDP

	Delucchi U.S. motor vehicles (% GDP)		ECMT (EU road and rail) (% GDP)
	Low	High	(Average of 17)
Accidents	0.59%	2.10%	2.5%
Congestion	0.57%	2.25%	N.A.
Air pollution (health)	0.41%	7.52%	0.6%
Air pollution (other)	0.15%	0.88%	
Climate Change	0.01%	0.15%	0.5%
Noise	0.01%	0.25%	0.4%
Total	1.74%	13.15%	4.0%
Total (billions 1991US$)	104	787	210

The full quantification of the costs of externalities requires a number of steps. Each externality requires formulation of relationships between:

- the magnitude of the external by-products and the level of the source activity/output,
- the presence of the by-products and their effects on people, plants and animals, and
- the value society places on these effects/consequences (monetization).

Each of these steps involves difficult quantification issues. Quantifying the first link is complicated by the fact that most environmental damages vary both spatially and temporally. Ideally, models should be used that can relate changes in transport activity to site- and time-specific changes in congestion, air quality, noise, water quality, etc. The second link involves the construction of exposure-impact functions based on the evidence from clinical, animal and epidemiological studies. Varying levels of scientific uncertainty complicates the quantification. Once steps have been taken to quantify the effects of source activity, valuation or monetization techniques can be applied to determine the value that society attaches to these effects.[&]

Key Assumptions

Quantification of health impacts of air pollution have taken both damage-cost and control-cost approaches. Gómez-Ibáñez [1997] notes that studies using control costs of air pollution generally produce estimates about four times greater than those produced by damage cost. Social cost estimates of transportation accidents and health impacts of pollution are quite sensitive to the assumed value of life used in the analyses, and the literature includes wide variations in these assumptions.

Health Impacts of Pollution

Delucchi's estimated cost of human mortality and morbidity from emissions due to road transportation represent 0.4-to-7.5 percent of GDP, with particulate matter accounting for 81-to-93 percent of the total impact. He reaches the conclusion that "*air pollution policy has focused too heavily on ozone control and not enough on particulate control*." The health effect of particulate matter is a topic of ongoing research. The effects of road dust (and other natural substances) in comparison with carbon-based emissions of combustion, the relative effect of PM2.5 to PM10, and whether threshold concentrations are required to initiate health effects are of particular importance to transportation assessments. One can expect the range of uncertainty to be narrowed over the next decade.

Climate Change

Transportation is a major source of greenhouse gas emissions. Within Canada, transportation accounted for 26% of 1997 GHG emissions, with the two main contributors being passenger cars and commercial trucks (each of which was responsible for just over 27% of transportation GHG emissions in 1997). From his review of

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[&] There are two basic approaches to cost estimation of market goods—**damage cost** and **prevention cost**. Damage based methods determine the costs associated with the damage caused by the external influence, while prevention methods estimate the costs of mitigating the effects of the external influence. Conceptually, the estimation of damage costs is preferable since external costs are defined as the costs transport users impose on others. However, where damage estimates are uncertain, the estimation of prevention costs is more practical. Non-market goods (health, quiet, clean air) require valuation techniques, which can be classified under three categories: 1) revealed preference, 2) stated preference, and 3) implied preference. The revealed preference approach attempts to deduce the value individuals place on a characteristic from their market decisions. The stated preference approach attempts to determine the value by posing hypothetical questions to a representative sample of individuals. The implied preference methodology derives societal values from regulatory and court-derived costs.

available studies, Delucchi [2000, p.152] finds that estimates of the marginal damage costs of GHG emissions range from $1 to $20 per metric tonne and that they "tend, very roughly towards $10/tonne-$CO_2$".[∞] Using $3 to $20 /tonne as the estimate of global damage and evidence indicating that damages in the U.S. are 5 to 21 percent of global damages, Delucchi estimates that U.S. costs are $0.3 to $4.2/tonne of $C0_2$ emissions.

Noise

The damages caused by noise include loss of sleep, lower productivity, psychological discomfort and annoyance. These are hard to quantify, but because they are associated with a place, the quantity of damage is often viewed as resulting in lower property values. Predicted noise costs for typical urban traffic densities vary from U.S.$4.5/1000-pkm to U.S.$5.8/1000-pkm. The ECMT [1998] allocates road noise costs on the basis of an assessed total road-noise impact of 0.3% of GDP. It has lowered its 1998 cost estimate from its earlier 1995 values by adopting a higher base threshold [moving to 55 dB(A) from 50 dB(A)]. Delucchi's estimate of the U.S. road noise costs in 1991 is a range of U.S.$0.5 billion to U.S.$15.0 billion (or about 0.008 percent to 0.25 percent of GDP).

Noise is a major issue at airports. Charges are currently applied on commercial flights at over 60 airports throughout the world. Most airports apply a surcharge or discount on the landing fee, based on an aircraft's noise characteristics. However, none of the current charges have been derived by evaluating the actual harm caused by aircraft noise.

Congestion

From a policy perspective it is noteworthy that congestion impacts are correlated with air pollution, noise and climate change impacts. Thus, policy instruments that address congestion will also influence these other externalities and vice versa. Delucchi estimates monetary costs to range from US$11.4 billion to US$36.2 billion and non-monetary congestion cost to range from US$22.5 billion to US$99.3 billion. The combined total congestion costs represent about 0.57 percent to 2.26 percent of GDP. The ECMT [1998] did not attempt to value congestion costs "because congestion costs are so highly dependent on local factors, making generalizations difficult or misleading".

Accidents/Crashes

The social cost of road accidents is generally considered high. The costs include medical expenses, lost productivity, vehicle repair and replacement, property damage, pain and

[∞] Instead of estimating damage costs, some researchers have estimated the energy or carbon taxes which would have to be imposed to generate reductions in CO_2 emissions. As compared to the projection of damage costs, the estimation of control costs is subject to a lower degree of uncertainty. In a model developed by Charles River Associates, the estimated carbon price to meet Kyoto is $259 for the U.S. and $361 (in US $1995) for Canada.

suffering, and the inherent value to society of a life. Delucchi's analysis of the cost of motor vehicle use in the U.S. found that the costs of motor vehicle accidents/crashes were second only to travel time costs in magnitude. However, like travel time, a large portion of the costs is born by the motor vehicle users (though insurance premiums in the case of accident costs). Thus these costs are not externalities.

The ECMT adopted an external cost of accidents that is much higher than the total social cost of accidents derived from official valuations for loss-of-life. It estimates the external cost of accidents (based on Swedish willingness-to-pay surveys placing the value of life at EU$1.4 million) to average 2.5 percent of GDP with a range of 1.5 to 3.5 percent.

The Royal Commission on National Passenger Transportation (RCNPT) estimated the accident costs of all intercity passenger modes, but considered that almost all of the cost was captured in user fees or insurance premiums. It assessed external costs of automobile crashes to be about 2 percent of total social cost and a negligible portion of GDP. The costs of public mode crashes were considered fully recovered by user fees.

INTERNALIZATION MEASURES[Π]

Facility Use Pricing

Congestion is a key factor in facility pricing. Efficient transport prices that reflected the marginal congestion costs of transport activities would not eliminate congestion; rather they would lead to an optimal amount of congestion which is worth its costs to society. The ECMT consider a system of vehicle and time-of-day specific charges to be cost effective and short-term feasible for Europe. While corridor-and region-specific charges are short-term feasible, full route-specific charges are considered to be longer-term strategies. Canadian studies have reached similar conclusions about the relative cost effectiveness of urban to inter-city roads. Tardif et al. [1999] noted that “While the cost of toll collection has decreased with the advent of electronic tolling, this cost is significant, particularly on lower volume routes.”

In the case of airports, social costs can be internalized through the establishment of appropriate landing fees and terminal user-charges. Landing fees designed to reflect marginal social costs would take account of noise and congestion externalities, as well as aircraft weight. At Heathrow, where peak-load pricing has been in effect since the early 1970s, peak-period landing and passenger fees have been 2.5 to 4 times off-peak fees.

Π Our focus is on market measures; however, we do not dismiss the importance of the other measures. Non-market measures such as information / moral persuasion, regulatory measures and infrastructure provision play an important role.

Taxes

Taxes have the dual impact of lowering total demand for transport, and of steering the market towards more efficient choices. The OECD [1995] notes that potentially the most efficient measure to reduce road transport demand would be a significant rise in the real price of fuel over the longer term. This measure, it is argued, could both reduce demand for, and improve the efficiency of motor transport. Substantial and steadily increasing fuel prices could influence life-styles, vehicle design, locational decisions, driver behaviour, choice of travel mode and length of journeys.

An OECD review [1997] notes that varying types of energy taxes already exist; however, these taxes have largely been imposed with revenue objectives rather than economic efficiency objectives. Another OECD report [1997, #175] notes that arguments for an elevated fuel tax are theoretically convincing; "however, such a policy has not yet been put into practice—primarily due to low public acceptance. In order to gain acceptance, such a policy would need to be designed and implemented in co-ordination with other tax and price policies so that its effects are revenue neutral."

Fee differentiation

Fee differentiation provides a linkage between price and the relative social cost of different vehicle types. Its advantage is that the infrastructure already exists to institute fee differentiation. Most countries have some form price differentiation in vehicle registration fees—bigger engine sizes and heavier vehicles pay larger fees. Its principal limitation is that it does not have a linkage to use.

Tradable permits

Tradable permits have been effective in applications such as SO_2, which involve a few concentrated pollution sources and widespread effects. Concentration of sources also makes the logistics of allowance trading administratively manageable and enforceable. However, CO_2 emissions are not so concentrated. Small, dispersed sources in transportation, residential/ commercial, and the industrial sectors are far more important in controlling CO_2 emissions than they are in controlling SO_2 emissions. This creates significant administrative and enforcement problems for a tradable permit program if it attempts to be comprehensive.

Tradable permits in the transportation context appear to be somewhat more appropriate for addressing climate change initiatives than for addressing other externalities. In that application, they would be more efficiently directed at large organizations such as railways, airlines and major long-distance trucking companies. The Tradable Permits Working Group [2000] of Canada's National Climate Change Process concluded that tradable permits might be effective if imposed at the fuel distribution chain, upstream from final emitters.

It is unlikely that any one measure will provide the proper impetus for all modes, or even all situations within a single mode. Coordination of a wide range of measures will be required to achieve a reasonable alignment of the price of transportation as perceived by users with the total social costs.

EXPERIENCE

The EEA notes that almost 20 percent of all environmental tax revenues (including car taxes) "…are related to transportation (excluding transportation fuels)." It suggests that, although these taxes may influence car *ownership,* there is "…hardly any evidence that they lead to a lower aggregate level of car *use."*

In the past decade, there has been a noticeable shift in taxation driven in part by environmental concerns. This is essentially *revenue recycling.* Speck and Ekins cite European of examples with respect to transportation. In 1990, for example, Sweden reduced personal income taxes on the order of 4.3 percent and introduced a package of environmental taxes—including CO_2 and SO_2 levies. Many countries have followed suit.

Differentiated fees

There is a movement to externality-differentiated fees in Europe. Sweden has addressed the competitiveness issue by introducing tax-and-rebate systems that are revenue-neutral within the affected sectors. It has introduced a charging system in aviation and shipping based on fees-and-rebates according to environmental properties of the aircraft or ship.

The European Union's implementation of the *Eurovignette Directive* represents a differential tax for heavy goods vehicles. Under the directive, the payment of road user charges in those countries without specific road tolls will change, and the vehicle tax will be scaled according to the damage caused to the environment and road infrastructure.

Noise pollution charges have been levied at airports in Belgium, France, Germany, Japan, the Netherlands, Norway, and Switzerland. In Switzerland, planes are taxed from 0 to 400 SF (C$500) per take-off depending on their noise class.

Congestion pricing

Congestion pricing initiatives date back as early as 1975 in Singapore, through area licensing and registration fees, and in Hong Kong through electronic road pricing. Singapore's Area Licensing Scheme (ALS) collection costs have been modest, (amounting to about 11 percent of revenue in the early years) and was extremely successful in reducing traffic congestion during the peak hours.

The other policy measures adopted by the Singapore government have also contributed to reduced congestion and emissions. The other measures presently in place include:

- a quota based marketable Certificate of Entitlement,
- annual license fees that escalate with the size of the engine and incur surcharges for vehicles older than 10 years (from 10% at 10-years, to 50% at 14 years and older),
- initial registration surcharge that is presently (November, 2000) set at 140% of assessed market value of the vehicle,
- a set of rebates for ownership of vehicles restricted to off-peak usage.

These initiatives, along with its vehicle quota system, are credited with significantly limiting the number of vehicles in Singapore. Anderson and Lohof [1997] report that without vehicle ownership and use disincentives, the number of vehicles in Singapore would have been 400,000 by 1992 instead of the actual number of 274,000.

The U.S. Variable Pricing Program (formerly called Congestion Pricing Program) is one of ten federally funded grant projects to study ways to reduce congestion on the nation's roadways. These grants were originally funded by *the Intermodal Transportation Efficiency Act* (ISTEA), and funding was continued under *the Transportation Equity Act for the 21st Century* (TEA 21).

Tradable Permits

U.S. policy discussions of interest to transportation include using tradable permits to provide more flexibility to emissions regulations for engines and fuels, and a pilot project to test the feasibility of using emissions trading to encourage telecommuting. Each is discussed briefly below [Parker, 2000]:

> *On May 13, 1999, EPA proposed more stringent Tier 2 emission standards for new motor vehicles. The standards would be phased in between 2004 and 2009 and require vehicle manufacturers to reduce NO_x emissions by roughly 90% below levels currently required under the* Clean Air Act*. Manufacturers with NO_x fleet emission averages below 0.07 grams/mile would receive credits that could be used in later years or sold to other manufacturers having difficulty in meeting the standards.*
>
> *U.S. legislation has been introduced that would encourage the use of emissions trading to promote telecommuting as a measure to reduce traffic congestion and control vehicular pollution. Specifically, the bill would authorize $250,000 in FY2000 for awarding a grant to the National Environmental Policy Institute (a nonprofit organization) to design a pilot trading program in conjunction with the Department of Transportation,*

CANADIAN INITIATIVES

The traditional approach to road funding in Canada has been to treat roads as a public good and finance their construction and upkeep out of general tax revenues. Since the 1950s, there have been 10 provincial or federal inquiries examining the way roads are financed. The last one, the 1991/92 Royal Commission on National Passenger Transportation (RCNPT), was firmly in the camp of making road taxes explicit—that is, letting the motorist know that the taxes paid are specifically for the upkeep of the road. However, no government has admitted that any particular tax is really a price for using the roads. Finance Ministers tend to make a link between motorists and fuel taxes, particularly when they increase the tax rate. However, in a legislative sense, there is no direct connection between any tax and road use. The term "road-user tax" in Canada is a judgement call, not a legal distinction.

A major factor in this lack of movement on internalizing the external costs of transportation is the lack of public acceptance. The high profile negative reaction to New Brunswick's toll highway and the avoidance of tax-based measures by the of the National Transportation Climate Change Table are indicators of this lack of acceptance. The strong reaction to British Columbia's recent discussion paper of a broad set of market-based initiatives for road users provides additional insight. The *National Po*st's coverage (December 2, 2000) included an observation from Norman Ruff, a political scientist at the University of Victoria: "SUVs don't vote, but their families do."

Nonetheless, there have been some important changes since the 1980s. Consider:

- In real terms—that is, adjusted for inflation—this has been more than a 20 percent increase in road-related taxes. Real road expenditures, on the other hand, have fallen by 10% or so over this period.
- Since the RCNPT, the Confederation Bridge to Prince Edward Island has been built and new toll highways have appeared in Ontario (407), Nova Scotia (Cobequid Pass section of 104), and New Brunswick. One, Ontario's 407, was sold to the private sector after it was built.
- Montreal, Vancouver, Victoria have created agencies that both collect certain dedicated taxes or other revenues and help finance urban transit and roads.
- In Calgary and Edmonton the provincial government has agreed to turn over a portion of the fuel tax revenues (5¢ per litre out of a total of 9¢ per litre) collected in the urban area so as to provide the cities with dedicated funding for transportation facilities.

CONCLUSIONS

Conceptual Issues in Social Cost Internalization

There appears to be general agreement on the theoretical merits of internalizing transportation externalities. There is much less agreement on the magnitude and extent of transportation externalities and on the means of including externalities in decision making. There are also a host of concerns over the potential impacts of any moves towards further internalization, especially the public acceptance of higher transportation costs, and possible limitations on transportation that might accompany internalization.

Social Cost Quantification

The literature dealing with the external costs of transportation activity demonstrates a wide range in the estimated magnitude of the externalities, and to a lesser extent, a range in the type of individual cost items that should be included in any quantification of externalities. The predominant sensitivities are in the costs attributed to health effects and congestion effects. The underlying estimates of the value of life and value of time are critical. Ongoing research may well narrow the range of estimates, but it will remain substantial.

The external impacts of travel and transportation are highest in urban areas, to the extent that the largest impact components (congestion and health effects of emissions) are highly population-dependent. Climate change is the one identified external impact of transportation activity that is apparently independent of location and time.

The Means of Internalizing Social Costs

With respect to market-based internalization measures, it is unlikely that any one measure will provide the proper impetus for all modes, or even all situations within a single mode. Coordination of a wide range of measures will be required to achieve a reasonable alignment of the price of transportation as perceived by users with the total social costs. Fuel consumption-based taxes are the easiest means of affecting all modes, but will not address external costs such as congestion and will not adequately distinguish between locations where the emission from fuel consumption has serious consequences and those locations where the impact is slight.

Tradable permits in the transportation context appear to be somewhat more appropriate for addressing climate change initiatives than for addressing other externalities; and in that application, permits would be more efficiently directed at large organizations. In the upstream supply side of transportation, tradable permits have been shown to play an important role in providing flexibility and efficiency to command-and-control type regulations, although one of the more successful North American applications of trading was limited to a phase-in period of more stringent emission regulation.

For the most part, the theoretical and practical literature, as well as existing initiatives, has been focused on road transportation. Electronic toll collection systems are the most effective available measure to meet the time/location-dependent sensitivity of congestion and environmental effects, and would appear to be the best choice for high-density urban areas. Other forms of road-usage fees (fuel taxes, differentiated registration fees) would be more cost effective in intercity and lower density urban areas. In terms of timing, a differentiated schedule of registration fees, in combination with increased fuel taxation, is a possible interim step towards a long-term objective of urban road pricing and distance-based fees for trucks.

Experience with Social Cost Internalization

With respect to initiatives taken to internalize transportation's external costs, we note that while there has been much attention directed at social cost determination and allocation in the past decade, with the exception of a few isolated cases, little action has been taken. Further, where action has been taken it has been strongly tied to revenue objectives or to very specific environmental or related concerns.

OBSERVATIONS ON KEY ISSUES

Equity and political acceptance issues will accompany any movement towards efficient social cost allocation. Although use-deterrence would be among the consequences of a pricing regime to rendering transportation sustainable from an economic, social, financial and environmental viewpoint, modally targeted pricing violates the principal of modal equality (even if designed to counter intermodal inequalities).

The OECD and others have noted that *revenue neutrality* is critical to public acceptance of the internalization of environmental and other costs related to transportation. There is no reason to think that the situation would be any different in Canada. Without suggesting which Canadian taxes might be altered, we note that many EU member countries have (or are proposing to) reduced personal income taxes and social security levies as the means of recycling revenues.

Full social cost recovery pricing, or any other policy, is only feasible if it can achieve acceptance within the national, provincial and local political structures that would have to shoulder responsibility for it. Implementation would be expected to cause situations where those who can afford to pay continue to pollute and congest, and those who cannot afford the price use alternative modes, or do not travel or ship. There are no easy answers to such problems; however, we agree with the position taken by the ECMT and the RCNPT that issues of vertical equity are best dealt with through the general taxation base rather than by distorting pricing mechanisms that seek efficient allocation of resources.

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1 INTRODUCTION

1.1 Background

The Government of Canada has committed itself to placing greater emphasis on sustainable development in its decision-making. As popularized in 1987 by the United Nations World Commission on Environment and Development, *sustainable development* is defined as "…development which meets of the present without compromising the ability of future generations to meet their own needs." Over the past decade, this concept has evolved and been enhanced to address the issues specific to different sectors of the economy so that sustainable development is recognized now as meaning "… that economic, social and environmental considerations are integrated into decision-making." [Transport Canada, 2000].

Transport Canada has proposed to adopt a set of sustainable development principles that will further define how the Department interprets the concept of sustainable development and how it will apply these principles to transportation. Among the proposed principles included in Transport Canada's second sustainable development strategy (May 2000) are:

SOCIAL PRINCIPLES	*Safety and Health:* Transportation should be designed and operated in such a way that protects the safety of all people.
	Access and Choice: Transportation should provide people with reasonable access to other people, places, goods and services.
	Quality of Life: Transportation is a key ingredient in the quality of life of Canadians.
ENVIRONMENTAL PRINCIPLES	*Pollution Prevention:* Transportation needs should be met in a way to avoids or minimizes the creation of pollutants and waste.
	Protection and Conservation: Sound environmental protection and conservation practices should be applied to transportation.
	Environmental Stewardship: Management systems will be refined so that internal operations support sustainable development.
ECONOMIC PRINCIPLES	*Efficiency:* Policies and programs will support the efficiency and competitiveness of Canada's economy and transportation system.
	Affordability: Transportation systems should be affordable.
	Cost Internalization: We recognize the merit of "full cost pricing" whereby the costs of transportation reflect, to the extent possible, their full economic, social and environmental costs.

This report focuses on the final principle, that of *cost internalization.* We note, however, that cost internalization is also closely linked to several of the other principles. For example, internalizing the costs of transportation-related emission is also a well-recognized strategy designed to induce transportation users to reduce emissions.

Transportation can result in harmful effects on individuals and society that are not reflected by market charges and payments, and are thus not included in what the transportation user perceives as transportation costs. These social effects or *externalities* include congestion related costs, air and noise pollution, greenhouse gas emission, air, soil and water contamination, and death, injuries and property damage from accidents.[1] Taking a broad view, the transportation activities that generate such externalities include the construction of the infrastructure, the production, maintenance and disposal of vehicles, the provision of energy and fuel as well as the actual operation of vehicles. While the environmental externalities often fall upon transportation users and non-users, the accident and congestion externalities are largely confined to the user groups. In keeping with sustainable development principles, these externalities should be reflected in the cost of transportation, and thus taken into account when transportation decisions are made.

1.2 Purpose and Focus of this Report

In its first sustainable transportation development strategy, (December 1997) Transport Canada committed itself to developing a better understanding of the environmental costs of transportation. More specifically, it committed itself to the evaluation of the issue of internalizing the environmental costs of the various transportation modes and to developing a departmental position on the matter. As a first step in its evaluation of internalization of environmental costs, Transport Canada sought a review of the literature of social cost estimates—including environmental costs—for all transportation modes and an overview of the experience of various jurisdictions as they implemented policies designed to internalize social costs.[2] This report documents this initial review. Specifically, the key objectives of the present study were to:

- Outline what social cost internalization means, and what it is intended to achieve in the transportation sector;
- Outline key issues and constraints in identifying and quantifying social costs in the transportation sector;

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1 Transportation can also create external benefits—which are properly included in the definition of *externalities*. Typical of such benefits would be increased land values generated as the result of new transportation infrastructure. This report does not address external benefits.

2 We note that many of the policies have been adopted in response to specific concerns, such as global climate change or the financing of specific infrastructure components, rather than as the result of a desire to develop an appropriate and proper price for transportation.

- Identify the social cost estimates of transportation modes (air marine, rail and road) in Canada and other OECD countries;
- Assess the potential means to internalize social costs, such as pricing and regulatory regimes; and
- Based on the experiences of OECD countries, Singapore and Hong Kong, identify the key issues and considerations, which arise from internalization of social costs.

We understand that Transport Canada plans to use this review as a springboard for stakeholder consultations. These would be aimed at designing a strategy that maps the path to identifying and resolving conceptual, policy and practical impediments to the implementation of social cost internalization in Canada. It is hoped that this review will also feed into and complement the *Impetus Project,* a five-year research project led by the Economic Analysis Branch of Transport Canada. This task of this project is to create tools that simulate policy initiatives, and to assess their potential impacts related to the full costs, performance and competitiveness of the transportation sector.

1.3 Layout and Content of Subsequent Chapters

The balance of this report is divided into five chapters. In Chapter 2, we examine the definition of social costs and externalities, and the economic arguments for internalization. This is followed by a discussion of the limitations of the theory and the key issues. Together these form the conceptual framework for the study.

In Chapter 3, we examine the methods and data requirements for the quantification of externalities.

Chapter 4 examines internalization instruments with particular emphasis on market-based measures, including user fees, permits and differentiated fees.

Chapter 5 summarizes specific experience with internalization, including experience with carbon taxes, emission trading, road pricing and other schemes such Singapore's Certificates of Entitlement.

Finally, in Chapter 6 we present our conclusions and provide some observations with respect to related issues including: marginal versus average total cost costing, the practicality and the assignment of dollar figures to externalities, the equivalent treatment of modes and horizontal and vertical equity considerations.

2 DEFINITIONS AND CONCEPTUAL ISSUES

This chapter presents important definitions and an introductory overview of methods employed in impact assessment and valuation of costs. (We offer definitions of other terms as they arise, and provide a full list of acronyms in Appendix A.) The issues and methodologies introduced here are discussed in more detail in Chapter 3, Quantification *Methods and Data Requirements*.

2.1 Social Costs / Externalities

Delucchi [1997, Stanley G. Long, ed.] identifies the social cost of motor vehicle use as "the all-inclusive economic cost to society of using motor vehicles." The all-inclusive economic cost includes direct personal/private sector costs, public sector costs and external costs (or *externalities*). Economists use the term *externalities* to refer to direct effects of an activity on persons not directly involved in the activity. A number of variations of the definition of externalities exist in the literature, for example:

- One of the more succinct definitions attributed to DeSerpa is "*an externality is a relevant cost or benefit that individuals fail to consider when making rational decisions*".
- Nash [1978] indicates that a standard definition is "any interdependency between production and/or consumption functions that is not traded in the market".
- According to Baumol and Oates [1988] "an externality is present whenever some individual's (say A's) utility or production relationships include real (i.e. non-monetary) variables, whose values are chosen by others (persons, corporations, governments) without particular attention to the effects on A's welfare".

The European Conference of Ministers of Transport [ECMT, 1998] note the importance to further segregate externalities into 'technological externalities' that follow the above definitions, and 'pecuniary externalities'. The latter involve unintentional costs or benefits that are the result of changes in market prices. For example, an infrastructure investment aimed at reducing travel time for road users may have the unintended result of increasing profits for a restaurant located on the newly improved route; in which case, the restaurant owner benefits from a positive pecuniary externality. Pecuniary externalities result in transfers or redistributions within the economy, whereas technological externalities result in changes to the net output of the economy. This distinction is important to the treatment of equity issues, which we discuss later.

It is also important to note that economic costs include the *opportunity cost* of a good or activity. In the transportation context, this involves the cost of the lost opportunities of alternative use of land used for infrastructure or of time lost to travel activity.

Technological externalities are generally recognized to be a major problem within the transportation sector. The scale of the problem is highlighted in a recent study [Greene and Jones, 1997, p. 2] reviewing U.S. evidence on the unintended consequences of transportation:

> *In the United States, 43,881 lives were lost and over 3 million persons were injured in transportation accidents in 1994. Transportation is responsible for a major share of air pollution. Transportation vehicles generated three-fourths of U.S. carbon monoxide emissions, over 40% of fine particulates, 45% of oxides of nitrogen, and more than a third of hydrocarbon emissions. ...Especially in urban environments, transportation vehicles are a major source of unwanted noise and a significant consumer and shaper of land use, with concomitant environmental impacts.*

2.2 Economic Arguments for Internalization

Since the market provides no incentive for individuals or agents to take external social costs into account, there is a misallocation of resources. Internalization measures are those that bring the costs or benefits back into the decision maker's evaluation framework, thereby making them internal to market-based transactions.

This review focuses on the use of economic instruments to internalize social costs into market decisions. However, it should be noted that there are other methods of reducing the impact of externalities ranging from nationalization of the externality's source producer, to command and control type regulations that limit the offending by-product. California's Emerging Environmental Challenges Workshop [Milanes, et al., 1999] notes the interest in market-based policies:

> *The "polluter pays" principle provides the basis for many of the public policy approaches that have been developed for use by various state agencies. This principle promotes more systems-oriented, market-based policies, assigning the responsibility for consumption to the entity most directly responsible for generating it, so that any increase in consumption leads to higher costs, and any decrease in consumption leads to lower costs, for that person, team or organization. Application of this principle is changing the nature of regulations from the command-and-control approach to a systems-based approach in which efficiency is rewarded, and consumption is penalized.*

Externality pricing is one possible internalization measure. In an ideal regime, external social costs would be added to the price of the activity that produced them, such that incremental activity would only take place if total marginal social benefits outweighed total marginal social costs. The price that equals the true (i.e. all encompassing) marginal cost of an activity or consumption is referred in the literature as either the '*shadow price*' or the *'marginal-cost price*' for that activity/good. Such a price produces the theoretical optimal level of activity/production. Imposing theoretically-exact shadow prices to transportation would cause an adjustment in the traffic flow for each mode to a level where the cost of a marginal movement or journey would equal its social costs, and both would equal the value of the journey or movement to the marginal traveller or transporter.

2.3 Limitations of the Theory and Key Issues

The findings of a 1995 *Conference On The Full Social Costs And Benefits Of Transportation* held by the U.S. Bureau of Transport Statistics (BTS) reflects the range of views and some issues associated with social cost theory.

> *Although there were many areas of agreement, many important areas of disagreement or uncertainty remain. These include the relevance and importance of external or social benefits of transportation, conceptual uncertainties about which costs and benefits are or are not external to private decision making, and whether relevant costs and benefits can be adequately characterized as externalities. In general, substantial theoretical and methodological questions remain about what needs to be measured and how.*

2.3.1 Equity Issues

The above-mentioned BTS conference participants raised the issue of equity, but agreed that full social costing is important, regardless of the objective. Identified equity issues include horizontal equity and vertical equity concepts. The *horizontal equity* concept addresses whether those who benefit from transportation infrastructure pay appropriately for it. The vertical *equity* concept examines whether various segments of society such as the poor, aged or handicapped receive adequate benefits from public expenditures and investments in transportation. Participants concluded:

> *If equity is recognized as an issue in its own right, apart from economic efficiency, then several criteria must be used to determine fairness in transportation. Whether or not transportation users pay the full cost of transportation is only one factor in determining equity. Moreover, better information about the full costs and benefits of both transportation infrastructure and its use are likely to be critical to reaching efficient and equitable transportation decisions.*

The EMCT framework considers equity considerations within *pecuniary externalities*. It notes [ECMT, 1998, p47] that:

> *… if the aim is to maximize welfare (through efficient resource allocation), then pecuniary effects are not relevant. …. if distributional effects are judged to be "unfair" (i.e. another income distribution is considered to be fairer), income streams of different people or groups of people can be given different weights to account for social imbalances and used to adjust the outcome of the social cost-benefit analysis. However, from a theoretical point of view, it is more efficient to tackle distributional issues through the tax-benefit-system than with cost-benefit analysis.*

The Royal Commission of National Passenger Transportation (RCNPT) reached the similar conclusion that the full social costs of transport should be borne by those receiving the benefits from it. The Commission argued that, while there is a need to help the poorer members of society, it is fairer and more efficient to do this through general taxes and targeted programmes. In this respect, it is noted that a user charge is not the same as a regressive tax, since lower income individuals can (to a certain extent) avoid the charge by altering their consumption. [3]

A Transportation Research Board Committee for Study of Public Policy for Surface Freight Transportation [TRB, 1996] cites horizontal equity issues as one area of justification for user pay principles, but considers that vertical equity issues are different in freight transportation than other sectors. The committee contends that:

> *…even though freight transportation services are important to the poor, the arguments for free or subsidized provision are far less compelling for freight than for other services, such as education or health, that appear to be more central to equal opportunity.*

2.3.2 Practical Considerations

Other limitations relate the theoretical framework of shadow prices. The theory of optimal taxation (in which taxes are designed to acquaint transport users with the full social costs of their activities) is developed within the framework of perfect markets. The EC [1995] points out that:

> *…market failures, high transaction and implementation costs and classification problems could significantly undermine the cost-effectiveness of economic instruments. If markets do not function efficiently then obviously price signals will not be transmitted efficiently and the effectiveness of economic instruments will be impaired.*

---

3 In the context of charges to offset the social costs of transport, the principle of *horizontal* equity dictates that similar charges should be assessed on transport activities with similar social cost characteristics; e.g., operated by similar vehicles over the same (or similar) route under the same (or analogous) circumstances. This can be at odds with *vertical* equity, which dictates that those who have more should pay more or, at least, should not pay less. In this respect, any taxation structure that charges the wealthy more as a percentage of income than is charged to those of more modest means is considered *progressive*. Conversely, taxes that disproportionately affect those of lesser means are considered *regressive*.

Viscusi, et al. [1992] note that:

> *In practice, due to data limitations, technological and scientific uncertainty, and resource constraints, computing the precise tax rates to restore optimal resource allocation is an impossible task. .... The issue of regional variation is of particular concern with respect to the choice of the tax implementation approach. Truly optimal tax rates should vary on a regional or even localized level when environmental and/or health damages vary. .... Localized tax rates should account for the specific health and environmental damages of the emissions in the local area and any downstream consequences of those emissions. .... The practical application of incorporating health and environmental social costs in energy pricing necessitates the balancing of achieving optimality and effectively implementing the tax policy.*

In practice, policy makers consider these factors in determining whether regulation or economic instruments are more cost effective in dealing with specific externalities associated with specific activities/products. Discussion of economic instruments focus on methods of improving the tax system to better align usage costs with external effects rather than determining the optimal tax. The European literature uses the terms variabilization and differentiation in relation to road taxes/fees. ***Variabilization*** strategies shift taxation away from fixed fees such as vehicle licensing to usage fees such as fuel taxes and road usage pricing, thereby increasing the marginal cost of transportation.[4] ***Differentiation*** strategies increase the range of fixed fees according to the external cost—high fuel intensity vehicles or high emission engines incur a higher fee.

2.3.3 Short Run Marginal versus Long Run Marginal Costs

Economists are in agreement that short-run marginal social costs (SMSC) provide the correct conceptual basis for efficient pricing. In other words, transport users should bear all the additional costs that their activities impose on the economy. This includes the additional costs transport users themselves incur, but also the costs their activities impose on other users, on the government, on neighbourhood residents, and even on future generations. Short-run marginal social costs include the wear on the infrastructure from additional transport activity, but not the general obsolescence that occurs through the ageing of facilities.

Short-run costs vary by vehicle, time, route and location, and also according to the weather and seasons. Efficient prices, for example, should reflect the higher costs of road

4 In the context of using economic instruments and changes in taxation policy as a means of reducing transportation demand, Proost and Van Dender [1998] note that a revenue-neutral shift from fixed per vehicle taxes to variable per vehicle-km taxes could increase total vehicle utilization. They argue that average usage per vehicle would decline, but that lower fixed taxes would encourage the acquisition of additional vehicles.

transport in peak periods on congested routes. While road users take account of the marginal costs they incur through additional driving time and expense, they do not take account of the costs their activities impose on other drivers and on neighbourhood residents. It is argued, therefore, that a peak load charge is needed to close the gap between marginal private costs and marginal social costs. Similarly, it is argued that charges are needed to take account environmental and other damages that cause short-run marginal social costs to depart from short-run marginal private costs of transport activities.

While SMSC provide the appropriate conceptual benchmark, they may not be feasible to calculate short-run marginal costs. Moreover, taxes or charges designed to close the gap between private and social costs may vary greatly between regions, and change significantly from one period to the next. While several economists have focused on the development of reasonable proxy measures of SMSC, some economists, such as Friedlaender [1969] have argued that long run marginal costs are a more practical standard for the pricing of transportation activities. Since long run costs tend to be more stable than short run costs, their use facilitates planning and reduces risk and transactions costs.

2.3.4 Full Cost Recovery

The implementation of efficient transport prices may also have to be tempered to take account of the desire for the transportation system to be self-financing. While some would argue that non-transport users benefit from an efficient transport system and should pay some of the costs of providing the infrastructure, others, including the RCNPT, argue that these benefits are insignificant and that transport users should not be supported using general tax revenues. From this latter perspective, it is inappropriate for transport users to pay efficient prices based on SMSCs, if these prices do not lead to cost recovery.

Efficient transport prices will lead to cost recovery in particular circumstances, notably where infrastructure costs are characterized by constant or decreasing returns to scale. In the case of roads, Winston [1991, p. 115] notes that:

> *... if capacity and durability are jointly characterized by constant returns to scale, then the facility's revenue from marginal cost pricing will fully cover its capital and operating costs.*

While Small, Winston and Evans [1989] find that, for the U.S., efficient road pricing would lead to approximate financial break even, Gillen and Oum [1992, p. 581] believe the situation is different in this country:

In Canada where the majority of non-urban roads are of low density (and capacity) and the indivisibility[5] of capacity construction plays some role, the application of social marginal cost pricing is likely to produce a financial deficit in many instances.

ECMT [2000] make similar observations for Europe:

It should be noted that efficient prices do not generally coincide with coverage of total infrastructure costs (for example in railways efficient prices will in many cases leave substantial uncovered infrastructure costs; and for urban roads efficient prices will raise revenues substantially above capital infrastructure costs). In this context it has to be acknowledged that efficiency is not the only political consideration in setting the level of charges, and budgetary pressures at times result in increasing charges above marginal social cost levels. Moreover, full cost coverage is viewed as an important principle in some countries.

The ECMT [1998, p 82] address the issue of high external costs in urban areas (particularly congestion and pollution) with infrastructure costs and full social benefits more broadly spread across the transportation network. It distinguishes the efficient pricing in uncongested circumstances from that in congested circumstances. It estimates that half the costs of uncongested roads are independent of use and it would be inefficient to recover the full cost of this infrastructure with a usage charge. It recommends a partial shift from fixed fees to use-fees on uncongested roads and a full shift on congested roads

There is significant economic literature devoted to establishing the "second best" pricing rules where SMSC pricing does not lead to cost recovery. This literature (which is discussed in Gillen and Oum, [1992]) supports the use of license or access fee to cover at least some of the fixed costs of transportation activities. If such charges significantly reduce access to the transportation system, however, it may be desirable to generate some of the needed revenue by marking-up those transportation charges that vary with use above SMSC. In general, the literature indicates that proportion of fixed costs borne by use charges and by a licence fee should be set so that the overall welfare loss from discouraging road access and road use is minimized.

2.3.5 Social Cost Measurement

Whether economic instruments or regulations are used, guidance in determining the appropriate magnitude of intervention requires the measurement of the total social cost. In this regard Nash [1978] notes that:

5 *Indivisibility* in this context refers to the fact that road capacity must be installed in discrete units and the reasonable size of a capacity unit may be far greater than the specific demand. Thus investments will be made periodically rather as required in each time period. These are also known as *lumpy* investments. Much of economic theory, however, assumes that investment can be much more closely matched to demand.

> *…the theory of social cost measurement has been the centre of academic controversy ever since the publication of Pigou's classic work* The Economics of Welfare *in 1920 (Pigou, 1920). The debate has centred on two broad areas:*
>
> *1) The significance of divergences between private and social cost and their implications for the role of the state in a market economy.*
>
> *2) The principles upon which the measurement of social cost is to be based.*

As agreement on the first item of debate (the significance of the divergence) is dependent on measurement of social cost, resolution of the second area of debate is a precursor to resolving the first. However, the problems are significant. While the identification and allocation of the private and public costs can involve a substantive data and analytic exercise, these costs have a monetary basis to work from. Measurement of the external costs of non-market goods involves additional analytic steps (that are often quite complex) and the evaluation of policy instruments to mitigate external costs require the development of functional relationships where historic experience is extremely limited, if present at all. Evaluations often must be based on supposition of data and/or transfers of experience from other jurisdictions. These problems are explored in the next chapter.

2.4 Conceptual Framework of This Review

2.4.1 Transport as one of Many Sectors with Social Cost Impacts

This review deals with social cost internalization for the transport sector. However, externalities and their mitigation are issues in many sectors of the economy. To be truly effective in realizing economically efficient allocation of resources, all sectors of the economy should be treated the same way.[6] In this regard, the ECMT [2000] notes that progress on transportation efficient pricing requires more cross-ministry coordination of policy development and an expanded role for ministers of transport in fiscal policy.

There are two issues related to the breadth of coverage of policies dealing with internalization of externalities, 1) treatment of upstream/downstream consequences and 2) double/multiple counting.

Treatment of Upstream and Downstream Consequences

Some externalities that are associated with transport use are essentially *upstream* activities (for example, emissions during fuel production, transportation and refining, or emissions attributable to the production of steel used in vehicle manufacture). Others can

6 This becomes particularly important when dealing with economic instruments. A carbon tax or energy tax would address all sectors whereas a usage tax would be focused on transportation.

be thought of as *downstream* (for example, environmental damage caused by abandoned automobiles or the effects of urban sprawl made feasible by the availability of cheap automobile travel). There is no doubt that these have a causal relationship with transportation.

Starting with assertions of indirect energy consumption more than two decades ago, there are those who have suggested including *upstream* and, to a lesser extent *downstream* effects in social costs attributable to transport. As with virtually all economic activity, the production of transportation fuel (and other petroleum products) and vehicles and the construction of infrastructure require the consumption of resources that might (or might not) be priced to account for externalities. These costs, although indirectly attributable to travel and transportation, are outside of the transport accounting framework and there is general agreement among economists that they should be recognized by the industry sector directly responsible for them.

From an accountability perspective, it would be most effective to apply the externality price as close as possible to the entity with the power to restrain the costs concerned. The petroleum producer (*upstream*) and not the consumer would be the logical entity to directly pay for the externality costs associated with emissions (say, natural gas discharged into the atmosphere) occurring during fuel production. Of course, these charges would ultimately flow through to transportation (and other sectors) via the price of fuel. Transportation activity would also incur increased costs (whether fuel of other fees) in proportion to the external costs directly attributable to it.

Analogously in the *downstream* context, vehicle manufacturers or distributors could be charged for damage imposed by the improper disposal of their product. Again, such a charge would provide an incentive for these parties to arrange recycling and clean disposal. Should, for example, they (or provincial governments through the vehicle licensing system) institute a *deposit repaid on certified vehicle disposal* system, payment would still ultimately be paid by vehicle owners but only those who abandon derelict vehicles.

Even if it were practical to design a coordinated system without double/multiple counting to attribute *upstream* and *downstream* environmental externalities to transport, efficiency dictates that externalities be charged to the industry sector directly responsible for them. Accordingly, an internalization policy encompassing all sectors would not include *upstream* or *downstream* externalities as social costs of transport. This is not to say that upstream/downstream effects should be ignored in transportation impact evaluations in the absence of internalization measures. The case of alternative fuels is a suitable example. With internalization measures in place for all sectors of the economy, alternative fuels used in transport would be priced on the basis of the cumulative external-impact fees imposed at each upstream stage as well as the fee associated with the end-use impact in vehicle transportation. However, in the absence of internalization measures, the upstream impacts are an important component to be considered in a cost-benefit analysis of alternative fuel usage in transportation.

Double/Multiple Counting

Unintentional double-counting of social costs, because they have already been included in the equation or because of interrelationships among various deleterious social and particularly environmental consequences, can be difficult to avoid. This can cause systematic total cost over-estimation. Some examples are obvious—the portion of the cost of motor vehicle accidents covered by insurance paid by the vehicle owner. Double counting can be more subtle; for example, while land occupied by transport infrastructure implies a social cost, where previous owners were paid a fair market value for the land used, infrastructure costs as reported should already reflect the value of the land in its most valuable alternative use. There are questions such as whether the incremental harmful emission caused by stop-and-go and idling, that is clearly an interference or congestion cost, will be treated exclusively as such and not reappear under the *Human Health* and *Natural Environment* categories (below).

2.4.2 The Need for Full 'Internal' Cost Accounting and Cost Allocation

Application of social cost principles to transportation is further complicated by the fact that transportation involves a mix of private and public goods and services and fees and taxes that have been imposed as a revenue source rather than tied to partial or full social cost recovery. The economic efficiency argument for the internalization of social costs is tied to having total costs within the decision makers reference frame. In order for this to happen, the internal costs and revenues also need to be allocated on the basis of their costs and benefits. Thus, cost allocation studies become a component of social costing in the transport sector. The framework adopted by several major studies of transportation costs reflects this dual requirement.

The Royal Commission on National Passenger Transportation (RCNPT) both estimated and allocate full social costs of transportation.[7] Its framework encompassed both costs and revenues and made allocations of each to users and all levels of government. Separate tables were completed for each mode. Research and Traffic Group [RTG, 1999]

[7] *DIRECTIONS: The Final Report of the Royal Commission on National Passenger Transportation,* 1992, especially Volume 1, Chapters 3 and 18, and Volume 2, Chapter 3. Volume 2 of the RCNPT report (pp 76-80) offers an explanation of how tables of this nature may be interpreted.

used a similar but more detailed and focussed approach for the road mode in *Road Pricing and Climate Change*.

The RCNPT's accounting structure is shown in Table 1. A more detailed representation developed for the present study is presented in Table 2. Some of the explanation that follows is taken from the RCNPT report.[8]

Table 1: RCNPT's Social Cost Accounting Framework

	Modal Cost Responsibility		
Type of cost	Users	Others	Total
Infrastructure			
Environmental			
Accident			
Special trans. tax/fee			
Vehicle/Carrier			
Total			

Source: *DIRECTIONS: The Final Report of the Royal Commission on National Passenger Transportation,* 1992, Volume 1, page 37.

The accounting framework outlined in Table 2 (next page) is well suited to answering the question as to whether transport users are paying their own way. It allows us to identify the major costs of transport activities and to understand whether and to what extent transport users are being supported by government or by the general public, who bears most of the external costs of transport activities.

Delucchi [1997] adopted the framework summarized in
Table 3 for his social cost evaluation of motor vehicle use. Delucchi classifies motor vehicle costs into six categories and allocated the costs to six classes of motor vehicles. His full Table covers multiple pages in the referred article and illustrates the allocation of forty-two cost components to each of the six categories summarized in
Table 3.

While Table 2 looks at costs and revenues, Table 3 focuses solely on the cost side of the ledger; it cannot tell us to what extent motor vehicle users are not paying their full social costs. Tables 2 and 3 address the same general costs, but Delucchi's full table incorporates a more detailed analysis of cost components.

8 Chapter 2 of that report includes a detailed explanation/interpretation of the matrix representation used there.

Table 2: Representation of Real Resource Costs (and Revenues[9])

	COSTS (REVENUE)							
	Vehicle/ Carrier	Infra-structure	Travel Time	Accident	Global Warming	Human Health	Natural Environ't	Noise & Other
Subject Transport/Travel								
Other Shippers/Travellers								
Federal Government								
Provincial Governments								
Municipal Governments								
General Public								
TOTAL								

The framework underlying Table 3 is useful for a comparison of various cost elements and for an analysis of how specific policy, behavioural or technological changes will affect the costs of motor vehicle or other transport activities. Table 3 is complementary to the accounting framework outlined in Table 2. The principal difference is that Table 2 requires allocation of revenues as well as costs among three level of government, while Table 3 involve more detailed development of cost components but lumps one government cost category.

Table 3: Classification of Costs of Motor Vehicle (MV) Use Adopted by Delucchi

Personal Costs	Private Sector Costs		Public Sector Costs	External Costs	
Non-monetary Costs	Monetary Costs				Non-monetary Costs
1) Personal non-monetary costs of MV use	**2)** MV goods and services produced and priced in the private sector	**3)** MV goods bundled in the private sector	**4)** MV goods and services provided by government	**5)** Monetary externalities of MV use	**6a)** Non-monetary externalities of MV use **6b)** Non-monetary impacts of MV infrastructure

9 Revenue, portrayed as negative cost would include: vehicle licence fees (to the extent that revenue from them exceeds administrative cost), fuel tax (to the extent that it exceeds sales taxes that would be paid on other consumption), property taxes (to the extent that they might exceed those payable on comparable property), etc.

2.4.3 The Focus of This Review

The focus of this present review is on externalities of transportation activity (Items 5 and 6-a in Table 3). There are several studies that have focused on the environmental costs of transportation. These studies are less concerned with full cost determination and allocation than with environmental cost identification and valuation. Bein [1997] for example, identifies and classes transportation costs into four quadrants (Table 4).

Although Table 4 does not indicate who bears the costs of transport activities (and is therefore less informative than Table 3) it does highlight the main categories of transport costs. The non-market costs in Table 4 pertain to the "non-monetary costs" in Table 3, while the market column covers what was referred to in Table 3 as private and public sector "monetary costs". While Bein's classification scheme is appealing because of its simplicity and clarity, it is less comprehensive than the frameworks in either Table 2 or Table 3.

Table 4: Bein's Classification of Transportation Costs

	Market	Non-Market
Internal	Road construction and repair Vehicle repair and maintenance Vehicle purchase and licensing Insurance payments and deductibles	Travel time User pain and suffering from accidents Do-it-yourself repair & maintenance Travel discomfort and stress
External	Insurance disbursements Subsidized road and parking Traffic law enforcement Emergency services Reduced property values due to noise	Air and noise pollution Land use impacts Congestion delays imposed on others Community severance Accident pain and suffering of others

The ECMT [1998] identifies the types of external effects that are relevant to internalization policies (Table 5). While pecuniary externalities are of interest because of their distributional implications, the main focus of this paper is on the technological externality costs associated with infrastructure use (i.e. the upper right hand column in Table 5). Table 5 provides a broad perspective on transportation externalities, but, as compared to Tables 2 and 3, it offers a less detailed and useful organizing framework for the cost elements that are of major interest.

As indicated, while *infrastructure provision* lends itself to cost benefit analysis as a component of the investment decisions, it is *infrastructure use* that lends itself to internalization measures. It is this subset of external effects that is the focus of this review. Within the quantification section of our review we highlight the treatment of air pollution and climate change in the road mode. It is important to emphasize, however, that efficient allocation of resources depends on the development of tools for both efficient pricing and efficient investment decision-making. Moreover, transportation pricing and investment are complementary. It is difficult to determine whether new infrastructure capacity is required, if prices have not done their job of efficiently rationing use of existing transportation capacity. At the same time, efficient prices may not convey the correct signals to transport users if the transportation system has not been built to the standards required by the type and volume of traffic derived from a thorough assessment of the costs and benefits of the associated investment.

Table 5: ECMT's Classification of Transportation Externalities

Externality Type	Infrastructure Provision	Infrastructure Use
Technological Externality Costs	Ecological and socio-economic separation Aesthetic costs, destruction of landscape, separation effects, etc. >> relevant for cost benefit analysis	Air pollution, noise, climate change, accidents, etc. Depletion of energy and other natural resources **>> relevant for Internalization**
Technological Externality Benefits	Fire protection due to roads in old cities >> relevant for cost benefit analysis	No relevant effect identified
Pecuniary Externalities	No growth: Distributional effects (e.g. bypass road) >> relevant for cost benefit analysis Growth: Productivity effects, access to remote areas. >> relevant for cost benefit analysis	

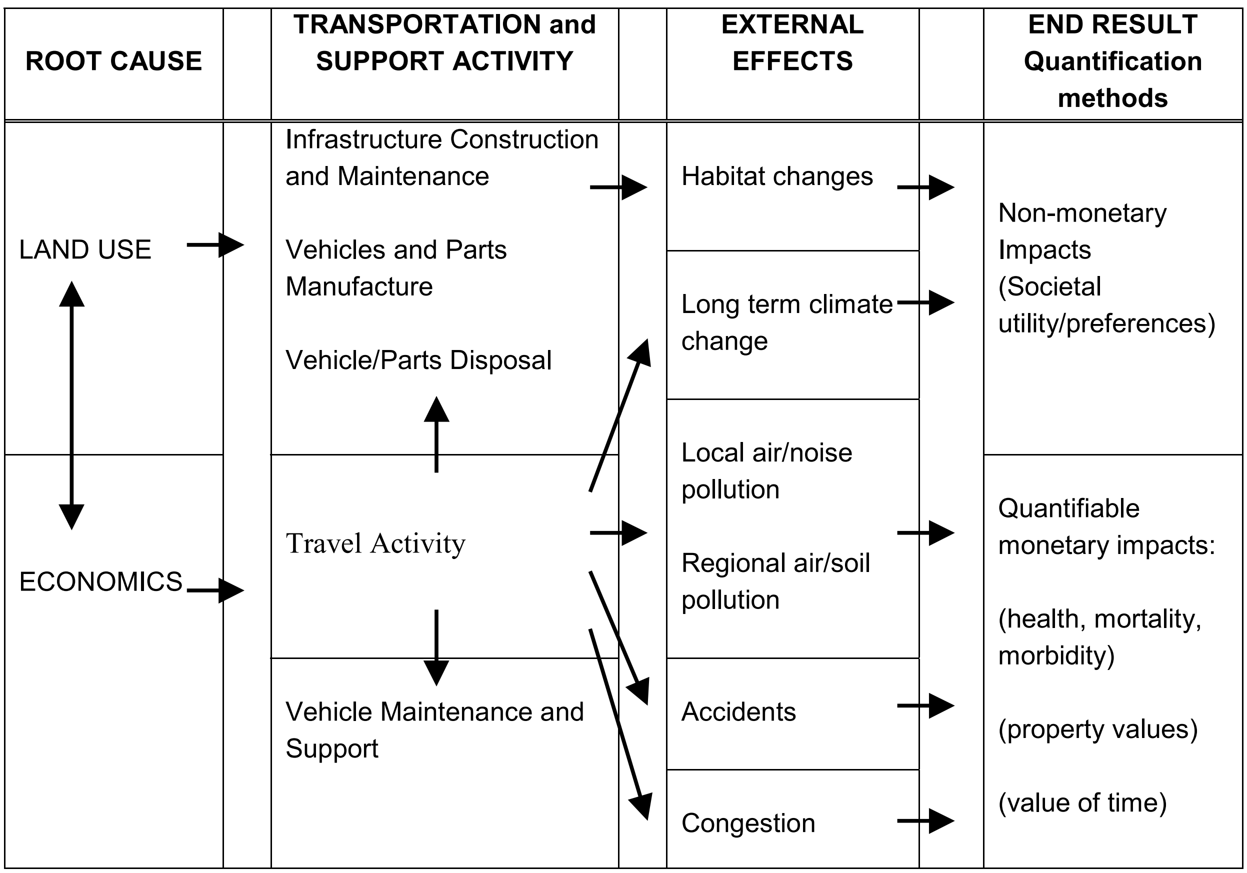
We note that the terms of reference and initial discussions with the steering committee for our particular study led to a focus on *infrastructure use* and on a subset of the external impacts of infrastructure use. We have selected Table 4 and Table 5 to illustrate our focus. This does not mean that we recommended these as preferred approaches to social cost evaluation in the transportation sector. We do recommend that Transport Canada adopt the framework of the RCNPT (as expanded in Table 2) in pursuing full social cost accounting. All of the other frameworks discussed above are essentially subsets of the RCNPT framework.

3 QUANTIFICATION METHODS AND DATA REQUIREMENTS

3.1 Transport's External Impacts

Transportation activity imposes external impacts on present and future generations. These impacts are illustrated in the cause-effect chart of Figure 1. The major focus of this paper is on the external effects of travel activity. As indicated, most, but not all, of the external effects of travel activity are quantifiable, although, as we discuss below, the measurement and evaluation of these impacts is a significant challenge.

Figure 1: Transportation Cause and Effect Chart



3.1.1 Transportation Use Externalities

Wear and tear of the infrastructure from transportation activities constitutes an externality so long as users are not faced with charges that reflect the damage their activities impose. Heavier vehicles cause greater wear and tear. For example, trucks and especially heavy axle trucks do greater damage to roads than automobiles.

Local air pollution from internal combustion engines have deleterious effects on health and the natural environment caused by carbon and rubber particulates, heavy metals, carbon monoxide and photochemical smog. They affect personal health, the general quality of life and the value of property.

Local noise pollution from transportation activity can affect the productivity and personal enjoyment of neighbouring communities. It also affects the general quality of life and the value of property.

Global climate change is believed to be exacerbated by carbon dioxide and other greenhouse gas (GHG) emissions from transport vehicle engines. Thus, there is a risk of deleteriously affecting future generations. Predicting such consequences involves complex forecasting, and valuation of their costs requires an assessment of how these impacts will affect the well being of future generations.

Accidents/crashes are a by-product of travel that can result in deaths, injuries and property damage. These give rise to externalities, to the extent that total accident costs are not reflected in drivers' insurance premiums. Accidental deaths cause short-run real monetary costs. Also, modern societies place a substantial value on human life as evidenced by their willingness to spend public monies on safety. Similar conditions apply to injuries with applicable costs for medical care, loss of productivity and pain – and suffering. Loss of productivity, including economic support provided to others, is longer term.

Interference cost is imposed by traffic elements (vehicles) on each other. It consists of the value of time lost plus the incremental fuel and other operating costs. Interference is different from other classes of externalities since much of the cost is internal for the traffic when considered as a whole.

3.2 Externality Cost Estimates

While the underlying methodologies can be applied to any mode, the emphasis of the more detailed studies has been on motor vehicle use and other modes using public infrastructure. The quality and originality of analyses/data is lacking in many studies, particularly for the freight modes. Murphy and Delucchi [1998] conclude from their review of the literature that:

> *…many of the current estimates are based on literature reviews rather than detailed analysis. Of course, this in itself is not necessarily bad. The real problems are:*
>
> 1) *many of the reviews rely on outdated, superficial, nongeneralizable, or otherwise inappropriate studies; and*

2) *many of the cost-accounting systems are not fully articulated, or else are a mix of economic and equity criteria.*

Thus, with a few exceptions, the recent literature on national social costs in the United States, taken at face value, is of limited use.

We concur with this assessment of the literature. Our discussion of methodologies draws heavily from Delucchi's well-documented series of reports, and from Environment Canada's AQVM3.0 User Guide. We also reference the methods used in the underlying studies to the ECMT [1998] policy discussion of internalization measures. The order of magnitude of the final estimates from Delucchi for the U.S. and from the ECMT for an average of 17 European countries is illustrated in Table 6. The combined impact ranges from 1.74% to 13.15% of GDP in the U.S. and an average of 4% (road and rail but excluding congestion) in Europe. Both passenger and freight vehicles are included in the cost estimates.

Table 6: Externalities as a Portion of GDP

	Delucchi U.S. motor vehicles (% GDP)		ECMT (EU road and rail) (% GDP)
	Low	High	(Average of 17)
Accidents	0.59%	2.10%	2.5%
Congestion	0.57%	2.25%	N.A.
Air pollution (health)	0.41%	7.52%	0.6%
Air pollution (other)	0.15%	0.88%	
Climate Change	0.01%	0.15%	0.5%
Noise	0.01%	0.25%	0.4%
Total	1.74%	13.15%	4.0%
Total (billions 1991US$)	104	787	210

The focus of this present section is on methodologies used to estimate external costs. We only briefly outline selected findings to illustrate key relationships. For a more detailed breakout of estimates, we note that:

- Quinette [1997] provides a summary of European estimates of transportation externalities.
- Krupnick et al. [1997] provide a summary of U.S. estimates of transportation's air pollution costs.
- Lake et al. [1999] provide a summary of Canadian estimates for highway modes.

3.2.1 Passenger Modes

A United Kingdom (U.K.) study by Pierson et al. [1994] illustrates the external costs differences between intercity and urban areas (and particularly during peak periods). The results of the study are summarized in Table 7. We have also included for comparison purposes a UIC study that included the same passenger modes with the U.K. as one of seven European countries evaluated. We note that peak-period costs of both automobile and bus are more than ten times those of intercity travel. While the relationship is largely driven by congestion costs, all external costs are larger in urban areas.[10] The table also illustrates that different studies often produce quite different estimates of external costs even when done for the same region and same time frame.

Table 7: U.K. Urban and Intercity Passenger Mode Externalities

	1990/91 Cost (ECU per 100 passenger-km)										
Source	Pierson et al.								UIC		
Cost component	Automobile London		Automobile U.K.	Rail Passenger London		Rail Passenger U.K.	Bus London	Bus U.K.	Auto (for all U.K.)	Rail Pass. (for all U.K.)	Bus (for all U.K.)
	peak	Off-peak	Inter city	Peak	Off-peak	Inter city	peak	Inter city			
Congestion	18.1	1.98	1.02	0.96	0.08	0.05	4.55	0.07			
Accidents	1.8	1.8	0.18	0.04	0.04	0.04	1.02	0.18	2.63	0.12	1.39
Air pollution	2.04	1.5	0.42	0.16	0.16	0.15	2.9	0.11	1.0	0.55	0.99
Climate Change	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.66	0.54	0.53
Noise	0.47	0.47	0.10	0.11	0.11	0.02	0.11	0.01	0.4	0.15	0.72
Total	22.5	5.8	1.7	1.3	0.4	0.3	8.6	0.4	4.7	1.4	3.6

Table 8 compares the different passenger mode estimates of the Royal Commission on National Passenger Transportation (RCNPT) for Canadian intercity passenger travel as of 1990 with Pierson et al.'s estimates for U.K. intercity travel (repeated from Table 7).

The most noticeable difference in the comparison is the cost assigned to climate change. The RCNPT adopted a prevention cost of $35/tonne for its estimates; Pierson et al. used a lower cost estimate.

3.2.2 Freight Modes

There are very few studies of externalities of North American freight modes. There are several detailed studies of highway infrastructure cost allocation to trucks, and Delucchi makes an allocation of his derived motor vehicle externalities among freight and

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[10] Johansson-Stenman and Sterner [1998] assume values of zero for the health effects of VOCs and NOx in the countryside, and allocate health costs for particulate matter (PM) at 1/5th those of average city effects (1/25th those of city centres). The PM effects in the county are considered to arise from carcinogenic effects through food production.

passenger vehicles. However, most cross-modal studies of freight-mode externalities are much less rigorous than the passenger mode studies.[11]

Table 8: Comparison of RCNPT and UK Estimates of External Costs#

1990/91 Cost (C$ per 1000 passenger-km)								
External Cost	Automobile		Rail Passenger		Bus		Air	Ferry
Item	RCNPT	U.K.	RCNPT	U.K.	RCNPT	U.K.	RCNPT	RCNPT
Congestion	0.00	5.61	0.00	0.27	0.00	0.38	0.00	0.00
Accidents	1.00	0.99	0.00	0.22	0.00	0.99	0.00	0.00
Air pollution	1.66	2.31	2.59	0.82	0.77	0.60	0.22	0.00
Climate Change*	4.10	0.11	3.82	0.05	1.69	0.05	8.99	1.92
Noise	0.00	0.55	0.00	0.11	0.00	0.05	0.70	0.00
Total	6.8	9.6	6.4	1.5	2.5	2.1	9.9	1.9

Based on 1.0 C$ = 0.55 ECU in 1991.
* Climate change estimates are based on much different costs/tonne of GHG.

The Transportation Research Board [TRB, 1996] has attempted to make order of magnitude estimates of the external costs, and level of subsidy, associated with freight transportation in the U.S. It has done this through a case-study approach involving four truck shipments, two rail shipments and two rail/Mississippi-barge movements. Each case involved an estimate of the marginal external cost of congestion, accidents, air pollution, noise and energy security. In addition, the marginal cost of public infrastructure (and related revenue) was estimated where applicable. The case results are summarized in Table 9.

As with the passenger mode, congestion is a driving factor in those modes where it is present. However, time-of-day scheduling can influence the congestion costs (to the extent that the study predicts total elimination of truck mode congestion costs if the case-study departure time is shifted). Another interesting finding of the study is that the range of subsidies is much smaller when shown as a percent of carrier cost (a 4.6:1 ratio) than when shown as $/tonne-km (a 10:1 ratio). We note that the results are not necessarily representative of the modes, but reflect the local conditions of specific case studies.

3.3 Assessment Methods Common to All Externalities

The remainder of this chapter deals with methodologies used to quantify the external costs of transportation use. In this subsection, we discuss those basic steps that are

11 The lesser attention to freight modes is possibly a consequence of their lesser role (in comparison with the private automobile) in energy consumption and associated emissions. We note that freight mode studies offer more rigorous treatments of infrastructure cost allocation than other externalities.

common to all impacts. In the subsequent subsection we discuss key assumptions/issues associated with each impact area.

Table 9: TRB Estimates of Freight Mode Subsidies

ITEM	CASES							
	1A	1B	1C	2A	2B	3A	3B	4
Externalities:								
Congestion	9	6	0	108	0	296**	1	9
Accidents	46	26	9	9	30	89	78	12
Air Pollution*	7	7	1	15	13	64	35	5
Energy security	3	4	0	3	3	17	5	1
Noise	2	0	1	1	3	21	13	8
Sub Total (Externalities)	66	43	12	136	50	487	132	34
Net infrastructure (cost – fees)	-12	1	-1	4	-7	-144	-9	-14
Combined Net subsidy (US$/truckload)	54	44	11	140	43	343	123	20
Combined Net subsidy (US$/truckload-km)	0.16	0.11	0.03	0.06	0.02	0.09	0.04	0.22
Subsidy as % of carrier cost	12	8	9	32	7	14	12	7

Legend to TRB Freight Mode Case Studies: ***

Case	Mode	Distance (km)	Commodity	Notes
1A	Truck	350	Grain	Direct route (100% empty return)
1B	Truck	400	Grain	Interstate (100% empty return)
1C	Rail	320	Grain	Shortline (40% empty return)
2A	Rail/Barge	2,435	Grain	Includes congested locks
2B	Rail/Barge	2,248	Grain	Rail bypass of congested locks
3A	Truck	3,749	Container	15% empty return
3B	Rail	3,495	Container	40% empty return
4	Truck	91	Local delivery	All urban, 125% empty/load ratio

Notes: truckload shipments: 36,287 kg for grain and 28,123 kg for container

* Includes GHG.

** Departure time shifts can eliminate the congestion cost allocation.

*** We note that the results of each case are very route- and commodity-specific and the application of these results to other cases may not be appropriate.

3.3.1 Basic Steps Involved

The full quantification of the costs of externalities requires a number of steps. Each externality requires formulation of relationships between:

- the magnitude of the external by-products and the level of the source activity/output,
- the presence of the by-products and their effects on people, plants and animals, and
- the value society places on these effects/consequences.

Each of these steps involves difficult quantification issues. The quantification of the first link is complicated by the fact that most environmental damages vary spatially and temporally. Ideally, therefore, models should be used that can relate changes in transport activity to site specific, time specific changes in congestion, air quality, noise, water quality, etc. The second link involves the construction of numerous exposure-impact functions based on the evidence from clinical, animal and epidemiological studies. Varying levels of scientific uncertainty complicates quantification of each linkage.

Once steps have been taken to quantify the effects of source activity (i.e. the first and second bullets above), valuation or monetization techniques can be applied to determine the value that society attaches to these effects (i.e. the last bullet above).

3.3.2 Valuation / Monetization Techniques

Several *monetization techniques* can be used to derive monetary values for externalities. Annex 1 of ECMT's *Efficient Transport in Europe* [ECMT, 1998] provides a detailed discussion of the potential sources of error and bias of the various valuation techniques. Levinson et al. [1996] provide a concise breakout of costing approaches and valuation techniques for non-market goods. They cite two basic approaches to cost estimation—**damage cost** and **prevention cost**. As the names imply, damage based methods determine the costs associated with the damage caused by the external influence, while prevention methods estimate the costs of mitigating the effects of the external influence. Bein [1997, pp 2-25] notes that the use of the prevention approach as a:

> *… determinant (rather than an indicator) of non-market values implies cyclical reasoning. …. Control cost estimates are based on the assumption that control standards rationally reflect society's values. In practice such standards are seldom applied consistently and may reflect political influences as much as rational valuation. Determining the most appropriate control level ultimately requires the valuation of non-market resources.*

Conceptually, the estimation of damage costs is preferable since external costs are defined as the costs transport users impose on others. However, where damage estimates are highly uncertain, the estimation of prevention costs is more practical. This applies especially to new environmental concerns such as climate change where research is still at an early stage.

We note that most recent social cost evaluations for transportation involve a damage cost approach. In pursuing damage cost estimation, the easiest costs to monetize are market goods (e.g. reduced employment, building damage, and crop losses). For example, general studies of the value of lost workdays have helped researchers monetize some of the health impacts of auto emissions. In estimating agricultural losses from ozone air pollution, researchers have turned to models [e.g. Howitt, 1991] that estimate the impact of reduced agricultural productivity on farmers (who face reduced profits) and consumers (who face higher food prices). [12]

Non-market goods (e.g. health, quiet, clean air) require valuation techniques. Levinson classifies the techniques under three categories: 1) revealed preference, 2) stated preference, and 3) implied preference.

Revealed Preference

The revealed preference approach attempts to deduce the value that individuals place on a characteristic (clean air, quiet, and safety) from their market decisions. The cost of an externality can then be determined by multiplying the decline in the quantity of the characteristic by the implicit value derived from analyzing market decisions.

Different methodologies have been used to calculate individuals' revealed preference. Levinson identifies some seven methodologies (See Appendix B). In *hedonic pricing,* researchers determine the additional amounts that individuals have been prepared to pay for a desired characteristic or, alternatively, the compensation they have demanded to accept an undesired characteristic. For example, to evaluate accident risks, researchers have looked at the risk evaluations indicated by the differing occupational wage rates.

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[12] While our focus is on transportation use, we make the following observation with respect to the external costs of infrastructure. Although it is rarely feasible to completely repair damage done by infrastructure development to the natural environment and human health, there have been calls for assessment of charges on the basis of the cost of environmental restoration. If repair at the site of the damage is not possible, it has been argued that an equivalent creation of pristine environment elsewhere is warranted. By extension, one would presume that the external costs of fatalities and injuries would be dedicated to safety measures or health care to save equivalent lives.

In evaluating such an approach one can note that, in general, where land is developed, society values the pristine environment less than it values the developed land. Otherwise, the development would not have proceeded or would not proceed. There must be exceptions; however. One can presume that generally the social value assigned by Canadian society to restoring the natural environment—that is not actually being restored or to be restored—is less than the cost. Thus, another approach to costing the deleterious environmental consequences of transportation and the transportation infrastructure is indicated.

The relevant studies examine wages across a large number of occupations, attempting to statistically isolate the impact of risk from the other worker and occupational characteristics that influence wage differentials. The implicit assumption in these studies is that workers are fully informed about differences in risk and are mobile enough to trade off the risks associated with different jobs.

Similarly, statistical analysis can be used to calculate the impact of noise on the market value of buildings. The assumption again is the economic agents are making their decisions on the basis of full information. Since traffic noise can significantly affect all those who use the specific location, the decline in building values represents, at best, a very partial measure of the effects of noise. In a recent case study, Leversque [1994] undertakes a detailed estimate of the impact of airport noise, decomposed into loudness and flight frequency, on housing prices around Winnipeg International Airport.

Hedonic price analysis has also been used to evaluate differences in air quality. Researchers [e.g. Cropper and Oates, 1992] have assessed the implicit value individuals have placed on air quality by analyzing the different prices paid to purchase comparable homes in regions of the U.S. with varying levels of air quality.

Travel costs provide an alternative means for deriving numerical values. The value of a public recreational facility could be deduced, for example, from the travel costs people incur to visit it. Such an approach, however, would not capture the more enduring benefits of environmental good such as a park or nature reserve. Button [1992] has noted that such environmental goods have not only a “user value”, but also an "option value", representing the importance individuals place on having a facility available for their possible future use; and an "existence value", representing the satisfaction individuals derive from simply knowing the environmental good exists and is being preserved for future generations.

Stated Preference

The stated preference approach attempts to determine the value of a non-market externality by posing hypothetical questions to a representative sample of individuals. Sometimes referred to as *contingent valuation* methods stated preference techniques, determine a *willingness to pay* (WTP) for a non-market good or a *willingness to accept* (WTA) a level of compensation for the loss of a non-market good. There are a number of problems associated with contingent valuation methods.[13] *Cojoint Analysis* addresses some of the problems by asking individuals to make tradeoffs between two directly involved goods (e.g. quiet versus accessibility). Still, stated responses to hypothetical situations may provide a poor guide to real behavioural responses to the same situations.

Substantial progress has been made over the years in refining survey techniques used to calculate people's willingness to pay. In one recent study, Miller [2000] examines individuals' willingness to pay for a given reduction in mortality risk. He finds that derived estimates of the value of life differ significantly from one country to another, with estimated values bearing a systematic relationship to per capita income. The study also finds that, after controlling for other factors, estimates based on willingness to pay do not differ statistically from results based on assessment of the wage premiums paid to workers in higher risk occupations.

Implied Preference

The last category discussed, the *implied preference* methodology, derives societal values from regulatory and court-derived costs. It might be considered a subset of revealed preference techniques; however, revealed preference techniques draw from market transactions involving broad participation of society. The source of implied preference values is neither direct or market based. In the case of court awards, for example, the amount of compensation is influenced by the type of suits that are brought and by legal precedents. Moreover, there is an emotional factor that enters into court decisions on how to compensate specific accident victims and their families, which is likely to lead to results that differ from society's evaluation of abstract statistical risks. In general, the implied preference approach suffers the same problems as the prevention cost approach in that it presumes that these activities reflect societal values.

3.4 Externality-Specific Methodologies

The above section gives an overview of the basic steps involved in estimating the cost of any externality and the valuation methodologies used once an impact is determined. In this section and the subsequent sections of our quantification chapter we take a more

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13 Levinson, et al. [1996] identify three main problems: The first difficulty with any stated preference approach is that people give hypothetical answers to hypothetical questions. Therefore, the method should be calibrated to a revealed preference approach (with actual results for similar situations) before being relied upon as a sole source of information. The second regards the question of "rights". For instance, someone who believes he has the right to quiet will not answer this question in the same way as someone who doesn't. The third involves individuals who may claim infinite value to some commodity, which imposes difficulties for economic analysis.

detailed look at the key assumptions and methods employed in each of the major categories of externality associated with transportation use.

3.4.1 Air Pollution

Our principal references for methodologies used to quantify air pollution costs of transportation are Delucchi's publications on social costs [University of California, Davis Campus, 1997] and Environment Canada/Health Canada's Air Quality Valuation Model [Chestnut et al. 1999]. Both references take similar approaches in determining the health costs of a given level of pollution, while Delucchi's work involves additional modelling to derive the relative contribution of motor vehicles to air pollution.

The primary transportation-related pollutants affecting human health are:

- Ozone (O_3), which is chemically derived from emissions of Nitrogen Dioxide (NO_2) and Volatile Organic Compounds (VOCs),
- Direct Particulate Matter ($PM_{2.5}$ and PM_{10})[14] primarily associated with diesel engines/fuels, and
- Particulate matter from road dust (and to a lesser extent, tire-and-brake-wear).

The stages involved in determining the external health costs of transportation-based air pollution are:

1. Determine emission levels from and locations of transport activity,
2. Determine the chemical processes by which some emissions reformulate into harmful pollutants,
3. Determine the dispersion properties of air-borne pollutants,
4. Determine the exposure levels for affected neighbourhoods,
5. Formulate dose-response functions by age and health status to derive health effects, and
6. Assess values of the health impacts to determine the social cost impact.

Delucchi's work involved all six steps for transportation-based pollutants, while the Air Quality Valuation Model involves the last two steps for all air contaminants. Delucchi

[14] $PM_{2.5}$ and PM_{10} are abbreviations for particulate matter of 2.5 microns in diameter or less and 10 microns or less respectively. A micron is a micro-metre or 1/1000th of a millimetre.

reports on his approach in the first four steps (determining source emissions) in Volume 16 and on the last two steps (determining health costs) in Volume 11 of his social cost series of reports.

Determining Source Emissions

While the quantification of air pollution damages has been evolving as a science over the past decades, it is still complicated by scientific uncertainties. For example local air quality problems, such as smog, are largely the result of low-level ozone, which is formed in a complex chemical reaction when nitrogen oxides and volatile organic compounds combine in sunshine. Because of the complexity of the process, scientists cannot quantify exactly how much low-level ozone is created by emissions from motor vehicles. While the production relationship has uncertainties, the presence of ozone can be measured. The measurement of ozone allows one to dissociate the uncertainty of the source linkage from the estimation of the physical affects of ozone on health and property. However, it still leaves the uncertainty about the contribution of transportation activity relative to other sources of emission.

Delucchi's approach is to model the contribution of motor vehicle transportation and the contribution of all other activities and apply the ratio to measured levels of pollutants. While the health affects are largely associated with urban areas, he also looks at crop damage and therefore derives pollution levels for all parts of the U.S. The U.S. Environmental Protection Agency (EPA) already generates an inventory of measured pollutants and estimated sources, using a computer model MOBILE5A for VOCs, NOx and CO emissions and PART5 for PM and SOx emissions from transportation activity. Delucchi's work in this area applies modifiers as deemed necessary to correct for model limitations he believes exist in the original EPA estimates.[15]

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15 His appraisal of the principal sources of error in MOBILE5A emissions from light duty gasoline vehicles (LDGV) were: 1) an underestimate of the number of cold starts (catalytic converters need to be heated to be effective), 2) underestimation of "off-cycle" emissions during high speed and hard accelerations, and 3) underestimation of the effect of air conditioning on emissions (particularly NOx). The modifiers that Delucchi applied to EPA's inventory of MOBILE5 predictions for LDGV-emissions (he deemed no adjustments were necessary for heavy-duty gasoline vehicles or for any diesel vehicles) is summarized below:

VOCs		CO		NOx	
Low	High	Low	High	Low	High
1.1	1.3	1.5	1.8	1.2	1.4

Once the source emissions are determined, he makes a number of simplifying assumption to keep the task of impact assessment for every region of the U.S. manageable. He acknowledges that these: "treat dispersion very crudely; use an extremely simple non-linear model of tropospheric ozone chemistry; [and] greatly simplify tropospheric aerosol chemistry." Readers interested in the details are referred to Report Number 16 in the *Social Cost Series*.

Determining Health Costs

Quantification of health impacts of air pollution have taken both damage-cost and control-cost approaches. Gómez-Ibáñez [pp 150-172 of Greene et al 1997] notes that studies using control costs of air pollution generally produce estimates of about four times those produced by damage cost (4 to 8 cents per passenger mile versus 1 to 2 cents). He notes that, while in theory most analysts agree that damage costs are a better approach, in practice control costs are easier to obtain and damage costs are often uncertain and incomplete. As we previously noted, the logic of using prevention/control costs as a better basis of recognizing the true costs is seen by many as flawed. Gómez-Ibáñez believes that:

> *…the case for using control costs is much weaker in the case of ground level air pollution, which has been the focus of fairly extensive research for the past 25 years, than for climate change, a more recent research topic.*

The formulation of a relationship between the presence of a pollutant and its health effects typically involves statistical analysis of the measure of interest across jurisdictions where the measure is present in varying quantities, or in time-series assessments for selected jurisdictions. These two approaches are discussed in documentation of the concentration-response functions in Environment Canada/Health Canada's *Air Quality Valuation Model* (AQVM) [Chestnut et al. 1999]. The concentration-response functions represent the causal linkage between the level of contaminant (e.g. ozone and particulate

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Delucchi also made adjustments to the particulate emissions predicted by PART5. He considered the model to underestimate PM from engines since the model is based on "a small number of tuned-up engines driven over a somewhat idealized test cycle." On the other hand he believes that PART5 overestimates PM from road dust. He raises a number of questions and cites more recent chemical mass balance analyses that support smaller ratios of road-dust-PM / vehicle-emission-PM. His adjustment factors applied to PART5 emissions were:

Emission Source	PM10		PM2.5	
	Low	High	Low	High
All vehicles	1.5	2.0	1.5	2.0
Road dust, paved roads	0.3	0.8	0.07	0.57
Road dust, unpaved roads	1.0	1.0	0.30	0.95

matter) in the atmosphere and human health effects. The issues raised with this approach are noted by Chestnut:

> *Some scepticism remains about whether these studies reflect a true causal relationship, primarily because a specific biological mechanism to fully explain and verify this relationship has not been demonstrated in clinical or laboratory research (Utell and Samet, 1993). However, epidemiological studies are consistently finding a statistically significant association between air pollution and mortality, using different study designs and locations, over a wide range of particulate matter concentrations, including levels well below the current Canadian objectives or U.S. standards. In addition, recent controlled animal exposure studies have begun to suggest plausible mechanisms by which severe effects, including death, may occur after concentrated ambient air pollution exposure (e.g. Godleski et al., 1996).*

As with transportation accidents, social cost estimates are quite sensitive to the assumed value of life used in the analyses. We note that that 'value of life' is a misnomer in that what is typically measured is a statistical value of altering the probability of death by small amounts. This value is then divided by the related decremental probability of death to get the value of one-statistical–life (VSL).[16] Methods employed include contingent valuation (surveys) and wage-risk studies (in which attempts are made to correlate incremental wage demands with an occupations risk of fatal injury). The literature also deals with estimates of the declining value of life with increasing age. Chestnut et al. [1999], in selecting value ranges for the AQVM3.0, provide a digest of the literature on the topic.

Environment Canada's AQVM3.0 User Manual cites much of the same background literature in its development of a value of life as Delucchi cites in his. Both discuss the key issue of 'mortality displacement' with respect to the time-series studies—the question of whether they represent a population subgroup that is very ill and already close to death. In assessing air pollution impacts, Delucchi assumes three classes of death: 1) representing those who were seriously ill and whose death is hastened by a relatively short time-period by air pollution, 2) those who were not seriously ill and lost a longer potential life-span and 3) chronic deaths where the death occurs some years after the onset of illness.

Delucchi used a lower bound of $10,000 and an upper bound of $50,000 for the first category and assumes that 100 % of deaths associated with time-series studies are close

16 Thus a finding of a WTP $250 for an annual reduction of the risk of death by 1 in 10,000, would be represented as a value that 10,000 people would be willing to pay to decrease their individual probability of death by 1-in-10,000. It takes 10,000 people to derive the equivalent of one statistical life (10,000 people times 1/10,000 probability) and the assessed value of that statistical life is $250 * 10,000 people = $2.5 million.

to death. He allocates a range of U.S.$1.0 million to U.S.$4.0 million for the second category. He notes that both values in the second category are lower than references cited. He did this to account for an age influence; many victims of air pollution are elderly and the value of remaining life decreases with age. He adopts the base range of this second category for chronic deaths and further assumes them to occur over a one-to-twenty year period, and uses discount rates of 2% and 8%, offset by an escalating value of life (with real income rise) of 1% and 1.5%, to get the present value.

AQVM3.0 takes the view that there is no evidence that mortality displacement dominates the time-series results. It adjusts for the age effect by assuming 85% of deaths are individuals aged 65 and over adopts an age-weighted average SVL range of Cdn$2.4 million to Cdn$8.2 million.

Delucchi's estimated cost of human mortality and morbidity due to particulate matter is compared with his estimates from all other pollutants from vehicles in Table 10. The total impact estimates represent 0.4-to-7.5 percent of GDP with PM accounting for 81-to-93 percent of the total impact. He reaches the conclusion that "*air pollution policy has focused too heavily on ozone control and not enough on particulate control*." He notes that ozone's health cost impact is ranked in nearly last place in the 'all other' emissions category. This is largely a result of the high cost placed on loss-of-life associated with PM impacts in comparison with the lower valued health impacts associated with ozone. However, he acknowledges that it might be due in part to "our inability to capture all the effects of ozone."[17]

Table 10: Delucchi's Estimates of Human Mortality/Morbidity Costs of Air Pollution

Pollutant	Cost Impact (billions 1991U.S.$)	
	Low	High
PM emissions from vehicles	16.7	266.4
PM from road dust	3.0	153.5
Total from PM	19.7	419.9
Total of all other vehicle emissions	4.6	30.1
Total health impacts of air pollution from vehicles	24.3	450.0

17 A few decades ago, the health effects of asbestos exposure and of lead in gasoline were improperly understood. Similarly, we were relatively unaware of the damage chlorofluorocarbons cause to the ozone layer and the relationship with skin cancer. As for the natural environment, as our understanding of the connectivity among members of an ecosystem grows, so does our estimate of the cost that seemingly innocuous damage to one species can cause. This opens the spectre of systematic under-estimation of the actual social cost of environmental disruption caused by transport (and other human activity).

Krupnick [Appendix in Chestnut et al., 1999] makes note in his peer review of AQVM that Ozkanak and Thursten, [1987] is a Canadian cross-sectional study, while Pope et al., [1995] is based on a U.S. cross sectional study. Delucchi's values of PM costs cite Ozkanak and Thursten as his low range and Pope et al. as his high range.

Both Delucchi and AQVM base their PM health effects estimates on North American research undertaken in the past decade. Earlier studies have not given PM as much attention. The ECMT, while deriving a total cost range in the same order of magnitude as Delucchi's cost range (0.25% to 3% versus 0.4% to 7.5% of GDP), associates most of this cost (all of it in the case of LDGV) with NOx and VOCs. The ECMT does not include road dust in its cost allocation; however, even with road dust removed from Delucchi's estimate, the ECMT unit cost ratio for the pollution cost of LDDV to LDGV is 0.7 while Delucchi's ratio is 1.9.

The RCNPT's view was similar to that of the ECMT. It estimated that particulate matter from transportation accounted for only 1.3 percent of non-natural particulate matter. As a consequence it selected only NOx and VOC for inclusion in its air pollution cost estimates.

The health effect of particulate matter is a topic of ongoing research. The effects of road dust (and other natural substances) in comparison with carbon-based emissions of combustion, the relative effect of PM2.5 to PM10, and whether threshold concentrations are required to initiate health effects are of particular importance to transportation assessments. One can expect the range of uncertainty to be narrowed over the next decade.

3.4.2 Climate Change

The Intergovernmental Panel on Climate Change [IPCC] projects that global temperatures will increase by 1.0 to 3.5 degrees Celsius over the next 100 years if action is not taken to reduce emissions of greenhouse gases (GHG)—mainly carbon dioxide, methane, nitrous oxide, ozone and chlorofluorocarbons. Climate changes may occur unpredictably and result in more extreme weather conditions. The anticipated consequences of these changes include: reductions in water supplies, reduced agricultural production, lower forest yields, loss of certain species, flooding in coastal communities, regional shifts in fisheries, harmful health effects from warmer temperatures and the spread of diseases carried by mosquitoes and other parasites. Transportation is a major source of greenhouse gas emissions. Within Canada, transportation accounted for 26% of 1997 GHG emissions, with the two main contributors being passenger cars and commercial trucks (each of which was responsible for just over 27% of transportation GHG emissions in 1997).

Climate change is a long-term global issue with only a small proportion of anticipated consequences of global warming directly deleteriously effecting Canada. Therefore, damage costs are different from those associated with other transportation externalities whose impacts are immediate and fall entirely on Canadians. In addition, quantification of the health, agricultural and other impacts of climate change is extremely difficult because of the considerable scientific uncertainty surrounding the nature of these effects. Recent scientific findings have raised new questions about the climate change projections produced by complex general circulation models that attempt to account for atmospheric concentrations of greenhouse gases.

Researchers have not applied a full damage-function approach to estimate the climate-change cost of motor-vehicle emissions, but they have attempted to generate estimates of the general costs of a kg of CO_2 emissions. This approach is possible because, in the case of carbon dioxide, it is reasonable to assume the environment is perfectly mixed, and a unit of discharge has the same effect regardless of its source. Based on available evidence, the underlying assumption that the damage function for GHG emissions is linear is also reasonable. Estimates of the costs of a Kg of CO_2 emissions vary depending on various factors, including researchers' interpretation of the scientific evidence, their choice of discount rate, and their treatment of uncertainty. For climate change impacts that extend far into the future, the choice of discount rate can have an especially significant effect on cost estimation. While some researchers argue that environmental impacts should be evaluated using the same discount rate that is applied to public investments generally, others contend that discounting minimizes long-term climatic effects and discriminates against future generations.

From his review of available studies, Delucchi [2000, p.152] finds that estimates of the marginal damage costs of GHG emissions range from $1 to $20 per metric tonne and that they "tend, very roughly towards $10/tonne-$CO_2$". He notes, however, that "if one compounds the uncertainty in key parameters, such as the discount rate, the number of lives lost due to global warming, and the value of those lives, the overall uncertainty can span several orders of magnitude". Using $3 to $20 /tonne as the estimate of global damage and evidence indicating that damages in the U.S. are 5 to 21 percent of global damages, Delucchi estimates that U.S. costs are $0.3 to $4.2/tonne of $C0_2$ emissions.

In applying these damage costs estimates to motor vehicles, Delucchi adopts a lifecycle approach that attributes to motor vehicle use emissions from any related activity, including feedstock recovery, fuel production, vehicle manufacture, and fuel end use. This methodology results in estimates of damages in 1990 from GHG emissions by U.S. motor vehicles of $5 billion to $37 billion globally and $0.3 to $8 billion in the U.S.

Instead of estimating damage costs, some researchers have estimated the energy or carbon taxes which would have to be imposed to generate various reductions in CO_2 emissions. As compared to the projection of damage costs, the estimation of control costs is subject to a lower degree of uncertainty. Control costs are a reasonable proxy measure to the extent that emission targets reflect the sacrifices society is willing to make on the basis of an informed understanding of environmental risks. One approach to estimating control costs is to look at the taxes required to meet the targets established in the Kyoto Protocol. The U.S. Energy Information Administration [1999], for example, estimates that, with a start date of 2005 for carbon emission reductions, the carbon price necessary to meet the Kyoto target ranges for $67 to $348 per metric tonne (1996 dollars). The lower price is more likely to the extent that the U.S. can take advantage of various flexibility mechanisms established in the Protocol, including especially international emissions trading. In a model developed by Charles River Associates, the estimated carbon price to meet Kyoto is $259 for the U.S. and $361 (in US $1995) for Canada. With emissions trading among Annex B countries, the carbon price falls to $80 for both countries. These data can be applied to information on carbon-intensity of transport activities to calculate the share of the overall costs of GHG reduction that would be borne by transport users.

The specific implications of higher carbon prices and other emission control measures for transportation are examined in a number of studies reviewed by Gómez-Ibáñez [1997]. While estimated control costs differ significantly, Gómez-Ibáñez finds that, on a per passenger mile basis, global warming costs are typically less than one cent, no matter how measured. In a study by Mackenzie, Dower and Chen [1992] undertaken for the World Resources Institute, for instance, climate change costs of motor vehicle use in the U.S. are estimated at 0.7 (1990) cents per passenger mile. A study by the European Federation for Transportation and the Environment [Kågeson, 1993] suggests that the climate change costs of automobile use are around 0.9 (1990) cents per mile travelled.

Economic studies generally assume that there are few opportunities for low-cost or no-cost reduction of GHG emissions. It is assumed that rational individuals would have already taken advantage of economically advantageous options for saving energy and reducing GHG emissions. To the extent such low-cost options exist, however, control costs would be lower than indicated by economic studies focusing on the responsiveness of energy demand to increases in fossil fuel prices. The Canadian Transportation Climate Change Table [1999] identified a number of promising alternatives to higher fuel taxes for reducing the GHG emissions of Canada's transportation sector. From the Table's optimistic perspective, once the cost-savings from more efficient transport practices are taken into account, the costs of reducing GHG emissions is only $5 per tonne (Table 11).

Table 11: Costs of Promising Measures to Reduce Transportation GHG Emissions

	GHG Reduction (Mt)		Cost/tonne
	2010	**2020**	
Passenger	10.1	11.4	$49
Road infrastructure	1.5	2.3	-$496
Road vehicles and	8.9	26.3	$64
Freight	7.0	8.1	-$3
Off-road	4.3	N/A	N/A
Total promising	31.8	47.9	$5

3.4.3 Noise

Noise is usually defined as unwanted sound. Physically, sound is perceived by a sensation in the ear as a result of fluctuations in air pressure. The most common measure of sound is the decibel (dB), which is a logarithmic measure of relative intensity defined by the following equation:

$$dB = 10 \, LOG_{10} (M/R)$$

where:

M = measured sound level

R = reference sound level

Sound measurements include frequencies beyond the human hearing range. Thus, sound measurement is usually weighted to exclude the measured content that is outside the range of human hearing (i.e. low and high frequency sounds are given a low weighting). The most common weight, is the A scale, and is denoted as the measure dB(A). Due to the logarithmic scale of noise, a 3 dB increment represents a doubling of noise intensity (i.e. $10 * LOG_{10}[2] = 3$ dB). However, the human perception of noise is such that an incremental 10 dB(A) is often associated with a doubling of the human costs of noise.

While noise measurement is relatively straightforward, determining the time-averaged impact of noise on specific sections of neighbourhoods is quite a complex process. It is generally estimated using models, which estimate typical source levels from traffic density, vehicle mix/operating-power/speed and apply distance-based dissipation rates according to ground cover, obstruction/barriers, and buildings status. We refer those interested in the detailed models and results to Levinson, et al. [1996] which provides generally accepted equations for noise estimation for road, rail, air and highway modes.

Levinson also identifies a number of studies performed over the years to measure the decline in residential property value due to noise and its associated vibration near highways and airports, but not for railways.[18] The damages caused by noise include loss of sleep, lower productivity, psychological discomfort and annoyance. These are hard to quantify, but because they are associated with a place, the quantity of damage is often viewed as resulting in lower property values. The cited studies use a noise depreciation index (NDI) which is the percentage reduction of house price per dB(A)-above-some-base. The average NDI for all of the airport noise surveys between 1967 and 1990 is 0.62 (%/dB(A)), the same value as for highways surveyed over the same period. Delucchi adopted a NDI range of 0.2 to 1.0 for his evaluation of highway noise.

Levinson et al. develop a property value model that can be used to derive the social cost of transportation noise for a range of input values. To determine the amount of noise damage produced by a transportation activity, one must identify the noise produced as a function of traffic volume and the location of residences near the activity. Also the house value must be known because the impact of noise is generally found to be a percentage reduction in house price rather than a fixed value.

By comparison, INFRAS/IWW [1995] estimates European noise cost per exposed person, derived from willingness-to-pay studies, and the estimated number of exposed persons at various levels of exposure. They allocated total costs based on macroscopic mode shares, and adjusting for the noisiness of modes. It is notable that the results for automobile noise are on the same order of magnitude as Levinson's model predicts for typical urban traffic densities (U.S.$4.5/1000-pkm versus U.S.$5.8/1000-pkm) even though they used widely diverging methodologies.

The ECMT [1998] allocates road noise costs on the basis of an assessed total road-noise impact of 0.3% of GDP. It has lowered its 1998 cost estimate from its earlier 1995 values by adopting a higher base threshold [moving to 55 dB(A) from 50 dB(A)]. The resulting unit-cost values are EU$2.95/1000-pkm for automobile noise and EU$9.12/1000-tkm for truck noise (compared with respective values for auto and truck of 6.81 and 22.93 in its 1995 study). Delucchi also undertook sensitivity analysis to the noise threshold. He found that going from his base case of 55 dB(A) to 50 dB(A) tripled the assessed road noise costs.

Noise is a major issue at airports and charges are currently applied on commercial flights at over 60 airports in the world. Most airports apply a percentage surcharge or discount on the landing fee, based on an aircraft's noise characteristics. However, none of the

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18 We note that public concern with the noise aspects of rail operations generally focuses on the use of whistles (or horns) at railway–highway grade crossings. As the purpose of the horn is accident prevention, there is a social cost trade-off involved—the benefits of using a loud horn to get the attention of motorists versus the cost of the unwanted noise to local residents.

current noise charges have been derived by measuring and evaluating the actual harm caused by aircraft noise. A study of Amsterdam's Schipol Airport found that optimal noise charges based on the social costs per landing would be about four times those currently in existence [Morrell and Lu, 2000].

Delucchi's estimate of the U.S. road noise costs in 1991 is a range of U.S.$0.5 billion to U.S.$15.0 billion (or about 0.008 percent to 0.25 percent of GDP). The fact that Delucchi's highest number is below the value used in Europe possibly reflects the higher population densities in Europe. If Transport Canada were to choose to transfer findings rather than develop its own costs, we believe that Delucchi's valuation would be more representative of Canadian conditions than the ECMT's valuation.

We would suggest that Transport Canada, in developing Canadian cost estimates, draw upon the modelling approaches adopted by Levinson and Delucchi. Levinson's model is similar to Delucchi's model for highway noise, but Levinson applied his model to a single corridor evaluation of three passenger modes, while Delucchi developed a national impact assessment for five classes of motor vehicles on six classes of U.S. roads. The data requirements include:

- Traffic volume (Vehicles per Hour separated by day and night)
- Speed in km/hr (highway, rail models)
- % heavy vehicles (highway)
- % daily traffic in peak hour (highway)
- %cost-reduction/dB(A) (noise depreciation index)
- Density (houses/square kilometre)
- Background noise levels
- Passenger per vehicle/train
- Height off ground of highway, railway (highway, rail models)
- Noise attenuation rates with respect to distance for each neighbourhood-type
- Average Home Price for each type of neighbourhood
- Discount Rate to convert total home depreciation into annual value
- Number of Years over which depreciation occurs

3.4.4 Other Environmental Impacts

While we have not explored the underlying methodologies in these areas, we note the following estimated external cost impact derived in Delucchi's work.

Table 12: Delucchi's Other Non-Monetary Externalities of Motor-Vehicle Use

Item Description	Value (billions 1991US$)	
	Low	High
Air pollution: loss of visibility, due to all pollutants attributable to m.v.	5.1	36.9
Air pollution: damage to agricultural crops, due to ozone attributable to m.v.	3.3	5.7
Air pollution: damages to materials, due to all pollutants attributable to m.v.	0.4	8.0
Air pollution: damage to forests, due to all pollutants attributable to m.v.	0.2	2.0
Water pollution: health and environmental effects of leaking motor-fuel storage tanks	0.1	0.5
Water pollution: environmental and economic impacts of large oil spills	0.2	0.5
Water pollution: urban runoff polluted by oil from motor vehicles, and pollution from highway de-icing	0.7	1.7

m.v. = motor vehicles

3.4.5 Congestion

Congestion affects all modes, but market forces and centralized decision making generally lead to a premium for peak-period travel in all non-road travel modes. Thus, much of the congestion literature is focused on highway travel. The physical phenomenon of highway congestion is well understood and generally accepted delay models exist. The issues in deriving the social costs of congestion rest more with the valuation and policy implication stages of analysis. From a policy perspective it is noteworthy that congestion impacts are correlated with air pollution, noise and climate change impacts. Thus, policy instruments that address congestion will also influence these other externalities and vice versa.

The ECMT [1998] did not attempt to value congestion costs "because congestion costs are so highly dependent on local factors, making generalizations difficult or misleading". It noted that its earlier green paper [EC, 1995] estimate of congestion costs—at 2% of GDP for the EU—was based on "erroneous assumptions". It notes that key factors in assessing congestion costs are the value of time assumed in the analysis, and the recognition that the optimal level of congestion is not zero.

Other European studies show that marginal congestion costs vary considerably according to the type of road (see Table 13). Newbury [1995] finds that marginal congestion costs are almost 1000 times greater on roads in central London during peak hours than on small rural roads. Bossier [1996] examined marginal congestion costs of trucks averaged over a year on various types of roads and found a significant, but much smaller variation.

Table 13: Estimates of Marginal Congestion Costs in Europe

London / UK; Newbury (1995)	Congestion Cost (ECU/100Vkm)
-rural roads	7.2
-rural dual carriageway	7.2
-urban central off-peak	4,795.0
-urban central peak	5,371.0
France -Intercity traffic; Bossier (1996)	
-rural road	5.85
-motorway	2.95
-national road	17.1

Delucchi's [1998, Vol 4 and Vol 8] approach to congestion costs is directed at determining the total national cost of delays on U.S. highways. His breakdown of external costs of delay is summarized in Table 14.

Table 14: Delucchi's Estimated Cost of Delays Imposed by Others (billions 1991US$)

Cost Item	**Lower Bound**	**Upper Bound**
Monetary Cost of Delay: forgone paid work	9.1	30.5
Monetary Cost of Delay: extra fuel consumption	2.3	5.7
Non-Monetary Cost of Delay: forgone unpaid activity	22.5	99.3
Total Cost	**33.9**	**135.5**

Delucchi's allocation separates monetary costs (foregone paid work and extra fuel consumption) from non-monetary cost (foregone unpaid activity). He estimates monetary costs to range from US$11.4 billion to US$36.2 billion and non-monetary congestion cost to range from US$22.5 billion to US$99.3 billion. The combined total congestion costs represent about 0.57 percent to 2.26 percent of GDP. The reader is referred to Volumes 4 and 8 of Delucchi's Social Cost Series for details of the full cost derivation across 10 income brackets and 12 user groups. The key steps taken in the derivation and associated values of non-monetary externalities of personal-use vehicle daily travel (which represents over 80% of total non-monetary delay cost) follow:

- Estimated fraction of time subject to delay (0.15 to 0.25)

- Estimated ratio of average speed with delay to average speed without delay (1.5 to 2.0)
- Estimated opportunity cost plus hedonic cost (utility of the experience) to get the value of time ($5.79 + $1.00 to $9.06 + $1.50) for non-monetary costs and ($16.08 to $20.62) for monetary costs.

Delucchi's characterizations of value-of-time for unpaid activities draw from previous studies that show a range of 33 percent of wage rate for low income groups to 55 percent of wage for high income groups.

Value-of-time estimates have also been derived from willingness-to-pay studies. One such study for the Netherlands [Hague Consulting, 1990] produced the value of time estimates for car and mass transit users shown in Table 15. For car users, the time-weighted average value of time was estimated at 5.3 ECU/h for commuting and 4.3 ECU/h for other trips. For bus users, the estimated values are 4.5 ECU/h for commuting and 2.6 ECU/h for other trips.

From the perspective of social cost internalization, it is the marginal cost of delay at a specific time on a specific road that is of interest rather than the total cost of delay. Determination of congestion shadow prices follow similar steps to those of Delucchi; however, they do not involve the aggregation to the national level. Efficient pricing for congested infrastructure is discussed in Chapter 5.

Table 15: Consumers' Value of Marginal Time Savings in the Netherlands

	Car (ECU/h)	**Bus, Tram, Metro** (ECU/ h)
Peak	4.98	3.96
Off-peak	4.43	3.23

3.4.6 Accidents/Crashes

The social cost of road accidents is generally considered high. The costs include medical expenses, lost productivity, vehicle repair and replacement, property damage, pain and suffering, and the inherent value to society of a life. Delucchi's analysis of the cost of motor vehicle use in the U.S. found that the costs of motor vehicle accidents/crashes were second only to travel time costs in magnitude. However, like travel time, a large portion of the costs is born by the motor vehicle users (though insurance premiums in the case of accident costs). Thus these costs are not externalities.

Some economists go further and argue that none of the productivity losses and pain and suffering borne by motorists or their families should be regarded as externalities. This is based on the assumption "that motorists understand and accept the risk they will be involved in an accident when they decide to drive" [Gomez-Ibanez 1997, p. 162].

If this assumption is not accepted, there is a significant portion of accident/crash costs that should be included within externalities. Delucchi allocates total motor vehicle accident/crash costs into four cells of a two-by-two matrix as illustrated in Table 16.

Table 16: Delucchi's Allocation of Accident/Crash Costs (billion U.S. 1991$)

	Monetary	**Non-monetary**
Private (or personal)	Repair and damage for self-cause crashes, insurance premiums for liability costs inflicted on others, 167.6 to 177.1	Pain and suffering costs of self inflicted crashes. 70.2 to 227.0
External	Property damage costs inflicted by uninsured motorists 26.0 to 28.0	Pain, suffering, lost productivity inflicted on/by others and not covered by insurance payments. 10.2 to 120.0[19]

Delucchi's allocation of the external costs of accidents has a range of $36.1 billion to $148.0 billion, which represents a range of 13% to 27% of his total estimated marginal cost of accidents, and 0.6 percent to 2.5 percent of GDP.

The ECMT [1998] cites the average total social cost of road accidents for 14 European countries to be 1.24 percent of GDP. The external costs (i.e. those not covered by insurance premiums) would be some portion of this cost. However, the social cost is based on official valuations of the loss of life for each reporting country which is often lower than the willingness to pay surveys indicate. The ECMT adopted an external cost of accidents that is much higher than the total social cost of accidents derived from official valuations for loss-of-life. It estimates the external cost of accident to average 2.5 percent of GDP with a range of 1.5 to 3.5 percent. The values are based on Swedish contingent valuation (willingness to pay) surveys placing the value of life at EU$1.4 million and extrapolating this value to other countries on the basis of average income.

We note that one of the principal difference between Delucchi's and ECMT's approaches is the allocation of self-inflicted (single-vehicle crashes) non-monetary costs. If this category were treated as an external cost (as many other studies do), Delucchi's cost estimate as a percent of GDP would be in a similar range as the ECMT estimate.

19 We have used the numbers shown in Delucchi's September 1998 Volume 9 report, which differ from the range 9.5 to 97.7 shown in the June 1998 Volume 1 report.

The RCNPT estimated the accident costs of all intercity passenger modes. It also considered a value of life based on contingent valuation WTP, but considered that almost all of the cost was captured in user fees or insurance premiums. It assessed external costs of automobile crashes to be about 2 percent of total social cost and a negligible portion of GDP. The costs of public mode crashes were considered fully recovered by user fees.

As an alternative to contingent valuation, the health effects of accidents can be estimated using quality-adjusted life years (QALYs) rating scales. These monetize the functional capacity losses that result from injury. Physician input is used in assessing the severity of various injuries and various dimensions of impairment are then converted into a utility measure by applying published survey estimates of the utility losses associated with different functional losses. The available QALY scales are described and reviewed in Miller, Pindus et al. [1995].

We note that none of the above studies has separated the role of alcohol in road crashes. Alcohol plays a significant role in motor vehicle crashes and its cost includes a relatively high tax (at least in Canada). In reality the tax might be seen as a revenue source rather than an internalization measure, and the public's acceptance of the 'sin-tax' might be based on conscience rather than recognition of its external costs. Nonetheless, its role in crash costs and its tax contribution (if it exists beyond the other external cost associate with its use) are relevant. Miller [pp. 281-314 of Greene, et al. 1997] reports that, of the estimated $367 billion in highway crash costs in the U.S. in 1993, $98 billion (or 26 percent) was attributable to driving with a blood alcohol level above 0.08. The United States Bureau of Transportation Statistics conference on social costs of transportation involved the following discussion: [U.S. BTS, 1996]

> *Although drunk drivers impose enormous costs on others, it is not clear that this problem is best viewed as a case of external costs. Some argued that drunk driving is an inherently irrational behaviour and may therefore fall outside the realm of welfare economics.*

We believe that a full social cost evaluation should include the role of all causal factors and any evaluation that Transport Canada undertakes in allocating the external costs of motor vehicle crashes should include an assessment of the role and revenue contribution of alcohol. In addition, TC needs to reassess the portion of costs covered by users through insurance premiums and the value of life assumed in the analyses to narrow the extremely wide range of external cost estimates for this category.

4 INTERNALIZATION MEASURES

Over the past decade the ECMT has explored internalization strategies for the transportation sector. The EC's [1995] green paper "*Towards Fair and Efficient Pricing in Transport: Policy Options for Internalising the External Costs of Transport in the European Union*" and the subsequent ECMT [1998] report "*Efficient Transport for Europe: Policies for Internalisation of External Costs*" provide details on the background and direction of their policy development. The general principles adopted by the ECMT in its development of an internalization strategy are summarized in Table 17. The focus is on aligning prices with total social cost while recovering the full long-run costs of infrastructure.

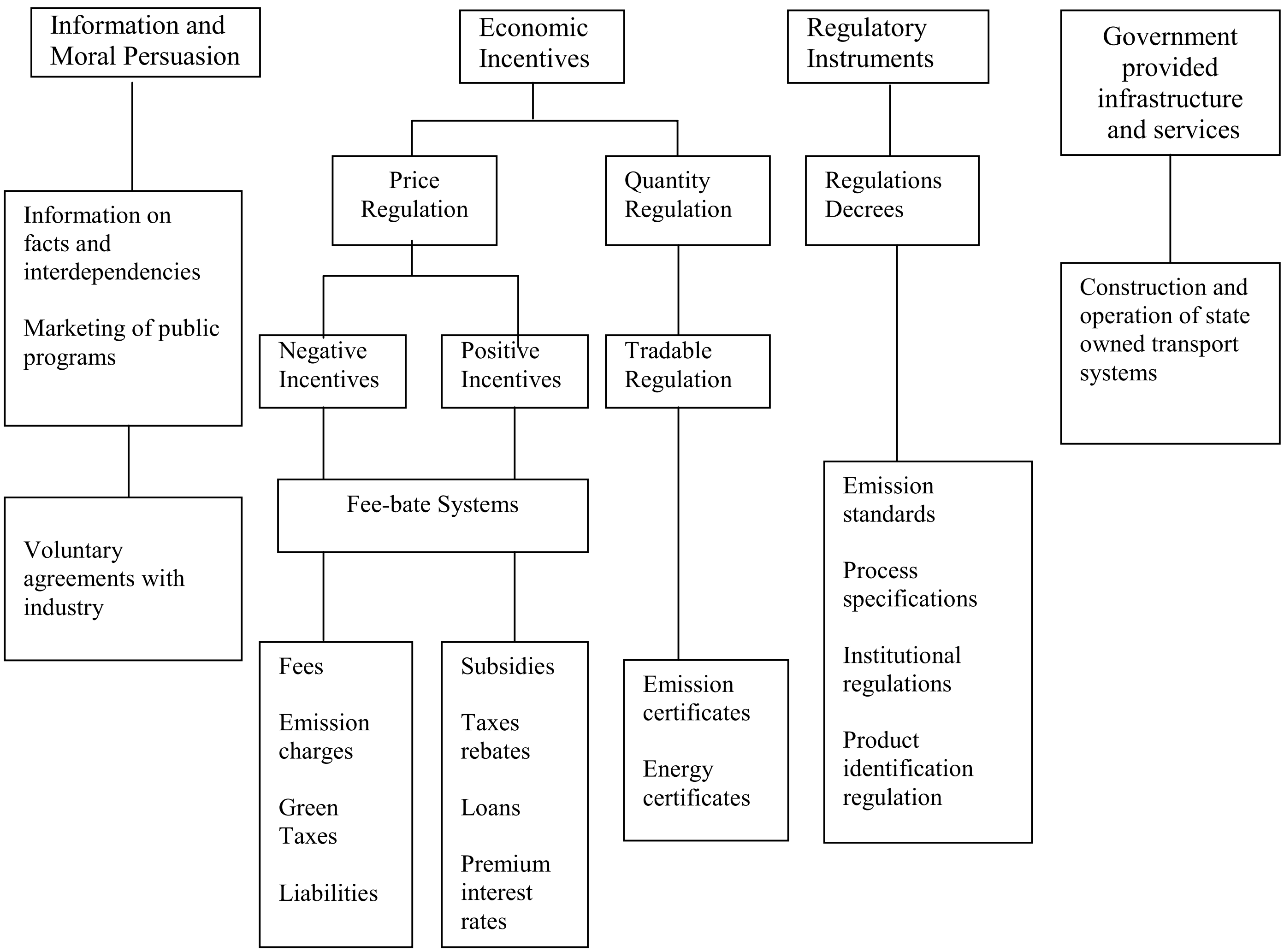
Table 17: Principles Adopted By The ECMT In Developing An Internalization Strategy

The aim of an internalization strategy is to increase both the fairness and the efficiency, in the broadest sense, of the European transport system. The principles of such a strategy can be summarised as follows:

- *Charges should be linked as closely as possible to the underlying costs. This will enhance both the equity and the cost-effectiveness of the system. The more charges are linked to costs, the larger the reduction in externalities and the improvement in welfare will be;*
- *Charges should, hence, be highly differentiated and behaviourial adjustment to reduce externalities has to be rewarded in the form of lower charges. Of course, the degree of differentiation should take account of transaction costs and the need to safeguard transparency;*
- *The price structure should be clear to the transport user. The publication of detailed accounts of the social costs and charges of the transport system is to be encouraged;*
- *Charging should be non-discriminatory across modes and nationals of different Member States, and revenues should flow to authorities in countries where the costs are factually caused (principle of territoriality);*
- *In all modes, transport prices of individual journeys should be better aligned with the total costs of these journeys to society (i.e. including accident, environment, noise, infrastructure and congestion costs);*
- *The full costs of all infrastructure networks should be recovered from transport users in the long run, unless infrastructure has been constructed for other policy reasons. This implies that an additional charge might have to be paid if charges based on the marginal infrastructure and congestion cost do not cover total infrastructure cost;*
- *Imposing additional charges for simple revenue raising purposes (i.e. over and above what is needed for cost internalization) is likely to lead to distortions, both in the economy as a whole and in the transport system. These costs should be compared with alternative ways of raising revenues.*

The ECMT (1998 p.56) provides a useful illustration of the various types of intervention government can take (see Figure 2). While Figure 2 shows four categories of intervention, its policy discussion focuses on economic instruments and their relationship to existing regulatory intervention. Nonetheless it is recognized that the other three categories are more prevalent.

Figure 2: ECMT illustration of Types of Intervention



Included in the table are three non-market measures:

- Information / Moral Persuasion
- Regulatory Measures
- Infrastructure Provision

We only briefly mention these as our focus is on market measures. In doing so we do not dismiss the importance of the other measures; one would expect each to play an important role. With respect to information, a Swedish EuroEST[20] (2000) discussion paper points out:

> *Information is normally regarded as a weak instrument when it comes to accomplish behavioural changes, nevertheless, it is very important. Without the dialog resulting from the flow of information there would not have been any movement at all towards sustainable transport. Perhaps the strength of information is to be supportive to other policy instruments.*

Infrastructure provision has long been the default response to congestion. Certainly, providing extra capacity will ease congestion but exacerbates all of the other externalities of transport. Nonetheless, Button [1998] notes that some economists have accepted that road pricing is not politically possible and have argued that in this circumstance, capacity should be manipulated so that the shadow price of investment incorporates traffic congestion costs.

The ongoing importance of command and control type regulations is also recognized by many. Baumol and Oates [1988] note that Pigouvian taxes can be more expensive to administer, less predictable, and more difficult to change on short notice, to the point that standards might be preferable in some and perhaps many situations. Also, while the ECMT discussions have focused on economic instruments, the role of regulation is still recognized. Its reasoning has progressed from its green paper to more recent policy deliberations. In its green paper [EC, 1995] it notes that:

> *…of the range of options, there are two basic approaches to curbing transport externalities: market based instruments (e.g. pricing) and direct regulation (also sometimes described as "command and control"). In comparing the attractiveness of policies belonging to the two classes, ideally, a case by case approach is needed. Nevertheless, there are a number of general insights to be drawn. Provided that economic instruments can be closely linked to the problem at hand, they are likely to be much more cost-effective than direct regulation because they allow citizens and businesses to rely on a variety of response channels to reduce the externality. The cost-effectiveness is likely to be particularly high when problems vary across space and in time: charges can reflect these differences, whereas rules—certainly Community legislation—end to coincide with jurisdictional boundaries. Economic instruments dovetail nicely into the market system and, therefore, generally require less red tape than comparable regulation.*

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20 The Swedish EuroEST project is a platform for action and common interest among Swedish government bodies in developing strategies for Europe towards sustainable transport.

More recently, the ECMT has resolved that [2000 pp.17]:

> *The most efficient approach to achieving sustainable development of the transport sector requires a combination of regulatory instruments (particularly for vehicle emissions) and restructuring of charges and taxes on the basis of marginal costs to provide incentives to reduce external costs to optimal levels.*

The ECMT [1998, p.81] considers the policy instruments itemized in Table 18 to be the most promising for social cost internalization of road use. The use of standards is still a component of their favoured policy instruments. Our particular focus is on the potential for economic instruments to internalize road transport externalities, largely as a consequence of its dominant role in transportation pollution. Nonetheless, we mention air and marine where applicable. The ECMT has focused on use charges and we discuss these in the next subsection. The use of tradable permits, which is identified as an economic instrument by the ECMT but not explored further, has been addressed more fully in the U.S. literature. We discuss it in the subsequent subsection.

Table 18: ECMT Policy Instruments for Internalization

Externality	Economic instruments	Other instruments
Air pollution	Use-charges	Vehicle standards, Fuel standards, Specific Urban Policies (parking, restricted access) Traffic management (e.g. speed limits)
Climate change	Fuel charges	
Congestion	Specific urban use-charges	Traffic management
Noise	Use-charges	Standards, Specific Urban Policies

4.1 Use Charges / Pricing Measures

In its evaluation of alternatives, the ECMT considers economic efficiency, breadth of applicability, barriers/ease of implementation. Its assessment of the relative merits of economic instruments directed at influencing marginal transportation use decisions are summarized in Table 19 [1998, p. 98].

The five categories of use charges considered include two variations of road pricing (one for only urban roads and another for all roads) a pricing scheme directly linked to heavy goods vehicles an indirect use fee attached to fuel consumption and a differentiated vehicle ownership fee. As indicated in Table 19, the evaluation considers each of the alternatives' linkage-strength to external cost causal factors (as well as its link to fixed cost recovery), its effectiveness with respect to each social cost component and its relative practical merits. The first four items in the 'linkages' section of the table indicate the need to differentiate charges on the basis of vehicle type, road type, distance-driven and time of day.

Table 19: ECMT Comparison of Policy Instruments of Use-Charges

	General Road Pricing	Urban Road Pricing	Electronic Km-tax for HGVs	Fuel charges	Differentiated vehicle tax
Application	General	urban	Trucks	General	General
Linkage to:					
Distance driven	++	+	++	+	--
Vehicle type	++	++	++	**0**	++
Road Type	++	-	--	-	--
Time	++	++	--	--	--

++ good link; + reasonable link; **0** poor link; - very weak link; -- no link

Potential Effectiveness in:					
Accidents	++	+	+	+	**0**
Air Pollution and Noise	++	++	+	+	+
Climate change	+	+	+		+
Congestion	++	++	**0**	**0**	**0**
Infrastructure	++	+	**0**	+	+
Practical Merits					
Short term availability	--	+	+	++	++
Acceptability of implementation costs	--	-	**0**	++	+
Cross jurisdiction distribution of revenues	++	++	++	-	-
Transparency	++	++	++	**0**	**0**
Ease of enforcement	+	+	**0**	++	+
Absence of legal obstacles or legislative burden	**0**	+	**0**	++	+

++ good; + positive; **0** neutral; - negative; -- bad.

A quick survey of the pluses and minuses in Table 19 indicates that the more effective options are considered to be variants of road pricing, but that they have a cost acceptability drawback. The 'effectiveness' subsection of the Table also highlights the correlation between congestion and other externalities that was noted previously.

4.1.1 Facility-Use Pricing

Congestion is one of the key factors in facility pricing. Efficient transport prices that reflected the marginal congestion costs of transport activities would not eliminate congestion; rather they would lead to an optimal amount of congestion which is worth its costs to society. Studies show that the ideal congestion toll would be sensitive to the varying traffic flow within the congestion period; rates would be graduated so that higher charges apply during periods of severe congestion. In terms of costing, this means that, for individual road links, there is not one but several marginal cost of delay estimates that are of interest.

Anderson and Mohring [1997] calculate the optimal congestion tolls for peak-period expressway travel in the Twin Cities Metropolitan Area. They estimate that if each vehicle was charged an amount equal to the costs it imposes on other vehicles by adding to the level of congestion, daily collections would amount to about $1.2 million, with over a quarter of this generated in the morning peak hour. Anderson and Mohring calculate that the average vehicle occupant during the morning peak period (with a $50,000 annual income) has a travel time value of $12.50 an hour, and incurs travel costs that are 26 cents a vehicle mile less than the full marginal costs of their trips. On the most congested 10-mile stretch of freeway, the cost that drivers impose on other vehicles during the morning peak rises to 62 cents per vehicle mile.

More generally, Anderson and Mohring point out:

> *…that the immediate effect of congestion pricing will be to make all but a small fraction of the population worse off. Our calculations also suggest, however, that tolling the entire road network would generate (gross of toll-collection costs) about $1.50 in revenue for each dollar of surplus travellers would lose. This being the case, we could compensate all losers and still have a substantial pot left over to finance reduced real-estate, fuel, and other taxes as well as transportation projects.*

Road Pricing

The first three alternatives (general road pricing, urban road pricing and HGV km-tax) in Table 19 are variants of road-use pricing. The ECMT [1998] considered general road pricing to be the most desirable long-term option.

> *A system of electronic road pricing covering all roads would come very close to being the perfect policy instrument. …. Because of the technological developments required, general electronic road pricing is a long run option.*

It considers urban road pricing and an electronic km-tax for heavy goods vehicles (HGVs) as the most cost effective starting points for a stepwise implementation. Urban road pricing addresses the highest cost areas for air pollution, noise and congestion externalities. A system of vehicle and time-of-day specific charges is considered to be cost effective and short-term feasible. While corridor and region specific charges are short-term feasible, full route-specific charges are considered longer-term technologies.

Canadian studies have reached similar conclusions about the relative cost effectiveness of urban to inter-city roads. Tardif et al. [1999] note that "While the cost of toll collection has decreased with the advent of electronic tolling, this cost is significant, particularly on lower volume routes." A study for New Brunswick Department of Highways [Price Waterhouse et. al. 1994] indicated that collection costs for a tolling system for the provincial arterial system would be approximately one-third of the revenues collected. These numbers are sensitive to the traffic volumes using the toll facility, and on higher volume facilities collection costs can be less than 10% of the revenues collected. "*Due to the high cost of toll collection on lower volume routes, widespread tolling as a mechanism for achieving full cost road pricing throughout the country does not appear feasible in spite of the advances in electronic toll collection.*"

The ECMT's focus on urban infrastructure and HGVs outside of urban areas might also apply to Canada. The principal advantage of electronic use-charges for HGVs is their ability to take account of the increased damage to the roadbed caused by heavy trucks. Studies for Canada and the U.S. have indicated that a possible inappropriate pricing structure for heavy axle vehicles is one of the major weaknesses of current road pricing regimes. A km-tax on HGVs also addresses problems of cost and revenue allocations across jurisdictions that are associated with existing fuel taxes. Low cost electronic tracking is seen to overcome one of the previous major obstacles of rate changes by jurisdiction. Electronic charges would have to reflect not only road damage costs, [21] but also environmental and other external costs that vary by distance and are vehicle-, route- and time -specific if they are to acquaint road users with marginal social costs of their activities. Even if low-cost toll technology could be implemented, limitations in our ability to identify, quantify and evaluate these external costs would hinder the development of efficient road-use charges.

Airport Pricing

In the case of airports, social costs can be internalized through the establishment of appropriate landing fees and terminal user-charges. Landing fees designed to reflect marginal social costs would take account of noise and congestion externalities, as well as aircraft weight. Gillen and Oum [1992] review the evidence documenting the gains from congestion pricing. At airports, the failure to implement congestion prices results in excessive peaking of traffic, time costs for passengers and higher labour and fuel costs. They show that at major airports, such as Toronto, where congestion problems exist, efficient landing and terminal fees would be higher during peak periods of the day and

[21] Some argue that the weight-damage relationship is not yet characterized and that inaccurate axle-weight technology is one of the problems to be addressed.

also over high peak months (March to October). Peak-load pricing would efficiently ration limited runway and terminal capacity, producing savings for air carriers and for passengers.

At Heathrow airport in Britain, where peak-load pricing has been in effect since the early 1970s, peak-period landing and passenger fees have been 2.5 to 4 times off-peak fees. In small airports without congestion problems, efficient cost-based landing fees are unlikely to lead to cost-recovery. Hence, if small airports are to be self-financing some form of "second-best" pricing regime is required. This could involve the introduction of licence fees for carriers and facility access fees for passengers. In addition or alternatively, landing fees could be raised somewhat above their efficient levels. The former is likely to be the preferred solution if the introduction of access charges would not significantly discourage airport use by carriers and passengers.

4.1.2 Fuel Taxes

Taxes have the dual impact of lowering total demand for transport and steering the market towards more efficient choices. Fuel taxes are the most important source of revenue in European countries, representing 70 percent of all transport-related tax revenue [INFRAS, 2000]. The OECD [1995] notes that potentially the most efficient measure to reduce road transport demand would be a significant rise in the real price of fuel over the longer term. This measure, it is argued, could both reduce demand for, and improve the efficiency of, motor transport. Substantial and steadily increasing fuel prices could influence life-styles, vehicle design, locational decisions, driver behaviour, and choice of travel mode and length of journeys. Car use, fuel consumption and emissions would be reduced. The announcement of long-term real price increase strategies would allow people to adjust their behaviour more easily and with greater certainty to a new relative price situation.

The ECMT [1998] see:

> *... the main benefits of fuel charges are that they are easy and cheap to implement and enforce. They are also seen as the optimal method to internalize climate change. However, the link with air-pollution, congestion and noise is not strong. Its main disadvantage is that "tank tourism" [cross-border shopping for lower fuel prices] exists when adjacent jurisdictions have significantly different taxes. From an infrastructure-pricing viewpoint, fuel consumption is not well correlated with marginal infrastructure costs for heavy-duty vehicles.*

Carbon taxes (based on the carbon loading of each fuel) have been strongly linked to climate change but have a poor linkage to local air pollutants. Viscusi [1992] notes that:

A carbon tax is a more difficult tax to update because of the need for additional information on carbon loadings of each fuel type and the inherent variations in carbon content across different sources of the same fuel. .... In the marketplace for fuels, the carbon tax will introduce an incentive to reduce consumption of high carbon content fuels, especially coal and natural gas. These marketplace adjustments may not optimally account for air pollution externalities; for example, natural gas has a high carbon loading but a relatively small adverse impact on the environment or health. [22]

Parker [2000] observes that:

In the view of most economists, the most efficient approach to controlling CO2 emissions would be a carbon tax. With the complexity of multiple pollutants and millions of emitters involved in controlling CO2, the advantages of a tax are self-evident. Imposed on an input basis, administrative burdens such as stack monitoring to determine compliance would be reduced. Also, a carbon tax would have the broad effect across the economy that some feel is necessary to achieve long-term reductions in emissions. .... Other tax schemes to address global climate change are also possible. For example, the European Community has discussed periodically a hybrid carbon tax/energy tax to begin addressing CO2 emissions. Fifty percent of the tax would be imposed on energy production (including nuclear power) except renewables; 50% of the tax would be based on carbon emissions.

An OECD review [1997] notes that varying type of energy taxes already exist; however, these taxes have largely been imposed with revenue objectives rather than economic efficiency objectives. The principal obstacle to common carbon, or energy, taxes is that they produce a redistribution of costs and incomes. The issues involve both equity considerations within a jurisdiction and competitive influences for cross-jurisdiction trade.

Another problem is the uncertain timeframe for tax changes to work through the economy.

Reduction of final energy consumption is constrained by rates of capital stock turnover (in the household sector, services and industry, not to forget infrastructures), the ability to pass the additional cost to consumers through a price increase (reduced if the sector operates in international markets, less so if all other trade partners adopt a similar measure) and the availability of more efficient or cleaner technologies domestically.

The study also notes the limitations of economic models in predicting the effectiveness of tax changes:

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22 Viscousi's reference to natural gas is in the context of utilities compared with nuclear and hydraulic sources. In the transportation context, natural gas is a low carbon fuel relative to gasoline and diesel.

This study should also stress the shortcomings of evidence on the effects of taxes (either positive or negative):

- *Modelling studies have a limited ability to simulate the long-term effects of a price-signal on technology. Neither do they adequately represent energy-related decision-making at the sector level, or real world constraints on the flexibility of different users, which determine responsiveness to a tax in the short term. "No-regret" reductions appear not to be represented in most global models looking at taxes. This automatically rules out the possibility of showing a competitive advantage from increasing domestic energy prices;*
- *Empirical evidence of the effects of differentiated energy prices on competitiveness is scant and based on opaque assumptions in macro-economic models;*
- *The effects of currently implemented taxes are still difficult to measure, inasmuch as other policies and measures are applied to energy use, on top of taxes.*

Use of Revenues

Another OECD report [1997, #175] notes that arguments for an elevated fuel tax are theoretically convincing; "however, such a policy has not yet been put into practice—primarily due to low public acceptance. In order to gain acceptance, such a policy would need to be designed and implemented in co-ordination with other tax and price policies so that its effects are revenue neutral."

The OECD [1997, WP4] also notes that:

...current experience shows that recycling [of revenue] can play a key role in assuring:

- *the credibility of a tax by demonstrating that the carbon/energy tax is not a new means to raise revenues under the disguise of environmental policy;*
- *the political practicality of a carbon/energy tax, since recycling's primary objective is to offset the negative macro-economic effect of the tax.*

The issue of what is done with the revenues applies equally to all market based internalization measures. We note that any suggestion of new charges on transportation (or any other sector) invariably elicits assertions that the nation's competitiveness will be compromised. Of course, these may be entirely false; however, a degree of concern is legitimate. The assertions normally hold that, even if Canada adopts a pricing regime that achieves local allocative efficiency through equal charges on all sources of emission, these charges would not apply beyond its borders. From a national perspective, Canada's competitiveness could be affected if its environmental charges are significantly higher than those of its main trading partners are, but the net effect need not necessarily be negative. Standard of living, economic growth, employment and prices would all be expected to change to some extent; however, the direction and magnitude of this change would depend on the disposition (recycling) of the revenues involved.

Sweden has addressed the competitiveness issue by introducing tax-and-rebate systems that are revenue-neutral within the affected sectors. It has introduced a charging system in aviation and shipping based on fees-and-rebates according to environmental properties of the aircraft or ship.

It might not be possible to keep all sectors revenue neutral. However, in aggregate, revenues from externality charges could be *recycled* by the government, to compensate those in the general public who must bear the (often not directly financial) costs of the activities concerned. Although in detail this would not be practical, it should be manageable without conspicuous distortion. For example, revenues from charges for smog causing emissions might be recycled through health care funding; revenues from a charge on carbon dioxide emission might be recycled in the form of a reduction in personal income taxes or the GST. Of course, governments would be equally at liberty to decide that the general public would be best served through a debt reduction programme; however, unlike the foregoing examples, this would tend to depress at least the shorter term national competitiveness.

If one is to presume a regime of exact revenue recycling, it seems reasonable to estimate that this will have at least neutral overall long-run economic consequences. It can be argued that the more efficient use of the transport system would reduce congestion and the need for government expenditure on infrastructure and healthcare—leading to improved competitiveness. There would, however, be a tendency towards shrinkage of transport intensive industries and a disproportionate impact on more remote regions of the country. Thus, we would predict deleterious shorter-term consequences—as industry readjusts to a new transportation cost structure. The effect on competitiveness of Canada's transportation intensive industry sectors and more remote communities would depend on the manner in which revenues are recycled. In this respect, we note that a subsidy program based on transport cost (for those industries that would otherwise suffer disproportionately from the externality charges) would tend to defeat the purpose of those charges and compromise the efficiency gains. A complex revenue-recycling program would also necessitate a substantial administrative and regulatory structure, with the inefficiencies that this implies.

4.1.3 Differentiated Fees

Fee differentiation provides a linkage between price and the relative social cost of different vehicle types. Its advantage is that the infrastructure already exists to institute fee differentiation. Most countries have some form price differentiation in vehicle registration fees—bigger engine sizes and heavier vehicles pay larger fees. Its principal limitation is that it does not have a linkage to use. Thus a heavy and inefficient vehicle that sees little use would be taxed beyond its social cost. However, this disadvantage can be mitigated by instituting a combination fuel tax (strongly linked to use) and differentiated fee such that the social cost causal linkages are appropriately priced. Referring back to Table 19, one can see that the combination of pluses in the *fuel-tax* and *differentiated vehicle fees* columns meets many of the same linkages as the *km-tax for HGV* option, and at a much lower implementation cost. The remaining shortfalls of the combined use-tax/differentiated-fee are the lack of transparency and the problem of distribution of revenues across jurisdictions. The latter is more of a problem in Europe but would still have some influence in Canada, where revenues from truck registration fees and fuel purchases might not be well aligned with the locations of use where the social costs would be incurred.

We discuss some of the externality-differentiated fees introduced in Europe in Chapter 5.

4.2 Tradable Permits

The Congressional Research Services (CRS) provides a good overview of emissions trading and much of the following is taken directly from CRS reports by Bearden [1999] and Parker [2000]

> *Conventional air quality regulations place fixed limits on emissions from individual sources and require them to install specific technologies to control pollution. However, compliance may be more economically feasible for some sources than it is for others. Emissions trading is a market-based alternative to conventional regulation which permits sources facing high pollution control costs to meet their emission limits by purchasing excess reductions from other sources that can afford to lower their emissions further than federal or state regulations require.*
>
> *Trading programs use either credits or allowances. Credits are emission reductions that a pollution source has achieved in excess of required amounts. Sources that have earned credits can sell them to others that need additional reductions. Allowances differ from credits in that they represent the amount of a pollutant that a source is permitted to emit during a specified time in the future. If a source estimates that its emissions will be less than its allowances, it can sell its excess allowances to other sources that need them. Some trading programs also allow sources to save credits or allowances for meeting limits on emissions in future years. This practice is commonly referred to as* banking.
>
> *For diffuse pollutants, decreasing total emissions over large areas through trading has the potential to improve overall air quality. For example, trading is well suited for pollutants such as nitrogen oxides (NOx), sulfur oxides (SOx), and carbon dioxide ($C0_2$)*

> *because they can drift far from their points of release.*[23] *However, trading is less suited for pollutants that remain locally concentrated because excess reductions in one area would not improve air quality elsewhere, and localized problems with air quality could arise from trading if sources clustered in one area are permitted to offset substantial increases in pollution with credits or allowances.*
>
> *Concentration of sources also makes the logistics of allowance trading administratively manageable and enforceable. However, CO_2 emissions are not so concentrated. Although over 95% of the CO_2 generated comes from fossil fuel combustion, only about 33% comes from electricity generation. Transportation accounts for about 33%, direct residential and commercial use about 12%, and direct industrial use about 20%. Thus, small, dispersed sources in transportation, residential/ commercial, and the industrial sectors are far more important in controlling CO_2 emissions than they are in controlling SO_2 emissions. This creates significant administrative and enforcement problems for a tradable permit program if it attempts to be comprehensive.*

The Tradeable Permits Working Group [2000] of Canada's. National Climate Change Process concluded that tradable permits might be effective if imposed upstream from final emitters at the fuel distribution chain:

> *Our analysis suggests that use of an upstream approach to CO_2 emissions from combustion of fossil fuels, with the requirement for permits imposed at some point in the fuel distribution chain, would be administratively efficient and would make it possible to substantially extend the coverage of GHGs under a TEP system. This expansion of coverage through use of upstream points of imposition where practical, coupled with coverage at the final emitter level for other GHGs where this is more practical (or the only option available), should assist in achieving a least-cost pattern of emissions reduction. Our broad as practical coverage option is intended to provide an initial illustration of the coverage that might be achieved under this general approach.*
>
> *The relative importance of the advantage provided by use of an upstream point of imposition for some sources of GHGs depends on the alternatives available to reduce such emissions. If alternatives are available to reduce CO_2 emissions from transportation and residential/commercial heating at costs similar to the expected permit price, the use of the narrower coverage, large final emitter TEP approach, coupled with such alternative approaches to reducing these "other emissions," might also fare reasonably well under the least-cost criterion.*

4.3 Closing Note

Anderson and Lohof [1997] note that the economics literature makes an important distinction between price and quantity instruments. Quantity instruments, such as

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23 NO_x is a precursor to ozone, and along with SO_x, can contribute to the formation of acid rain. $C0_2$ is a greenhouse gas that may contribute to global warming.

marketable permits and credit trading within caps, provide the pollution control authority strict control over the quantity of emissions. Price instruments, such as pollution taxes and fees, provide strict limits on how much a firm must spend to control pollution but do not limit the release of emissions. With uncertainty, the regulatory authority would not have good information concerning the costs of a quantity-based approach, or the environmental consequences of a price-based approach. Which type of uncertainty is more serious? If there are important environmental threshold effects, a quantity approach would be preferable. But few pollutants have that characteristic; most exhibit stable dose-response relationships.

Tradable permits in the transportation context appear to be somewhat more appropriate for addressing climate change initiatives than for addressing other externalities and in that application would be more efficiently directed at large organizations such as railways, airlines, and major long-distance trucking companies.

It is unlikely that any one measure will provide the proper impetus for all modes, or even all situations within a single mode. Coordination of a wide range of measures will be required to achieve a reasonable alignment of the price of transportation as perceived by users with the total social costs. Fuel consumption-based taxes are the easiest means of affecting all modes, but would not address external costs such as congestion and would not adequately distinguish between locations where the associated emission from fuel consumption has serious consequences and those locations where the impact is slight. With respect to the road mode, Gillen's [1997, p. 214] assessment is relevant:

The evaluation of alternative pricing tools seems to show that in practice, a government must use a mix of two or more charging methods in order to achieve high efficiency in the road transportation sector while attaining a cost recovery target. The road-pricing scheme recommended consists of three parts:

1. *a system of graduated per-kilometre fees for trucks based on axle weight which will improve the efficiency in the use of roads and promote an optimal investment in the durability (thickness) of the road system;*

2. *congestion tolls and environmental externality taxes which help to improve the efficiency of the usage of road capacity for urban and near-urban roads as well as achieve an optimal investment in road capacity (lanes); and*

3. *a fuel tax-license fee combination for cars on uncongested roads.*

5 EXPERIENCE WITH INTERNALIZATION MEASURES

5.1 European Taxation Experience

5.1.1 Overview

A recent draft report by the European Environmental Agency [EEA, 2000, draft] indicates that the focus on the use of environmental taxes has been increasing. Such taxes are said to be major tools "… to get the prices right and to create market-based incentives for environmentally friendly behaviour …" and to help implement the User Pay and the Polluter Pay principles. The EEA cites three reasons for the increased use of environmental taxes:

- The Kyoto targets will be difficult to achieve without additional policy instruments. Economic instruments are expected to contribute to achieving the target.
- The Cardiff-Gothenburg Process of moving towards the integration of environmental requirements into sectoral policies includes the internalization of external costs and the creation of 'fair and efficient' prices "… for which environmental taxes are a major instrument."
- The expected dispersal of traditional tax bases such as capital, labour and consumption due to the increased mobility of production and e-commerce increases the attraction of fixed and material factors such as energy, land and water as a tax base.

Use of the revenue from environmental taxes for fiscal reform (reducing personal income taxes and social charges) and for the funding of environmental projects was also cited as an advantage.

The EEA notes that almost 20 percent of all environmental tax revenues "…are related to transportation (excluding transportation fuels)." These include car taxes and it is suggested that although these taxes may influence car *ownership,* there is "…hardly any evidence that they lead to a lower aggregate level of car *use."* Their environmental impact is seen more as through tax-rate differentiation by emission characteristics or weight. The EEA report cites a study that suggests environmental externalities are approximately four percent of EU GDP "… of which only a small proportion is captured in relevant transportation taxes."

The report notes that the share of environmental taxes in the total European tax revenue has been slowly increasing and has accelerated at the end of the 1990s. For the most part, such taxes have been implemented at the member state level rather than at the EU level.[24] Further, it concluded, "… the evidence of the environmental effectiveness of green taxes is increasing".[25]

As reported in the latest survey [Speck and Ekins, 2000], European countries have had a long history of specific energy taxation dating back to 1917 in some instances. For the most part, energy charges have been intended as *revenue raising* as opposed to specific *policy instrument* taxes. Nevertheless, high taxes —in comparison to Canada—on energy have served much the same ends as specific policy instrument taxes.

In the past decade, there has been a noticeable shift in taxation driven in part by environmental concerns.[26] Energy or pollution taxes have been increased while other taxes have been lowered. This is essentially *revenue recycling.* Speck and Ekins cite a number of examples with respect to transportation:[27]

- In 1990 Sweden reduced personal income taxes on the order of 4.3 percent and introduced a package of environmental taxes—including CO_2 and SO_2 levies. The energy-related excise tax components of the package are not levied in proportion to the energy content of the fuel. Results have been mixed. As a result of charging a higher levy on leaded gasoline, the consumption of this fuel fell from 100 percent in 1986 to nearly zero by 1994. Despite the imposition of a carbon tax, CO_2 emission has risen slightly since 1993. On the other hand, the imposition of the SO_2 tax has resulted in the reduction in the average sulphur content. Sweden also allows a significant

24 The one exception noted is the implementation of the Eurovignette Directive (see Chapter 4).

25 Little evidence is offered in support of the last statement although additional work on the subject would appear to being offered in the final report. We also note that much of the work on environmental taxes relates to non-transportation externalities. Reference is also made to an INFRAS/IWWW (fall, 2000) study of the external costs of transportation, which was not available. In an annex to the draft EEA report, the authors note that there is some impact on vehicle consumption as a result of motor fuels but that the main short-term impact is substitution in response to tax differentials (e.g. leaded vs. unleaded gasoline). Other energy taxes (including carbon taxes) are seen to promote "…clear energy-efficiency improvements and fuel substitution." Motor vehicle use fees are seen as "…usually applied as a cost-covering charge. [The] evidence on effectiveness as an environmental policy instrument is still lacking."

26 We note that some of the tax changes—for example, those related to leaded gasoline—appear to have been prompted solely by health concerns rather than any specific transportation considerations. Nevertheless the health impact of using leaded fuel is one of the external costs of transportation activity.

27 There are a number of similar environmental levies in non-transportation areas. We also note that various energy, carbon, sulphur and similar levies apply equally to other sectors. For a more detailed, but somewhat out-of-date, description of transportation taxes see *Vehicle Taxation in the European Union* [EC, 1997].

reduction from the 25 percent VAT for public transport. There are similar reductions in taxes on hybrid and electrically powered vehicles.

- Belgium has reduced social security fund contributions by 1.5 percent replacing this revenue with a new energy tax. This shift was reported to be intended to “safeguard competitiveness and employment”. The new energy tax—which does not apply to diesel or LPG fuels—is quite low in comparison to the general excise levies for fuels (550 BFR per kL as compared to 19,910 BFR per kL).
- Throughout the 1990s, Denmark has reduced personal income taxes, employer social security contributions and other levies, and replaced them with a series of levies on electricity, water, waste, automobiles, CO_2 and SO_2. Interestingly, the carbon tax does not appear to be levied on gasoline consumption. Denmark has also introduced an “Owners Green Tax” as an incentive to shift to more fuel-efficient vehicles. Annual vehicle registration fees are based on weight and fuel consumption estimates. A provision has also been introduced to allow for some rebate of registration fees for cars that are scrapped.
- In 1996, the Netherlands shifted some of its personal income, corporate profits and social security taxes to energy and CO_2 taxes. The energy tax—first introduced in 1988—has been revised a number of times and is now based half on the carbon content and half on energy content of the fuel. The general level of the energy taxes is in the range of 2.5 percent of the general excise tax on the corresponding fuels. The Netherlands levy annual vehicle fees on the basis of the type and weight of the vehicle and the type of fuel used. Higher fees apply to LPG or natural gas powered vehicles. Electric vehicles are exempt. As a result of the Green Tax Commissions, tax rates on energy have now been indexed to inflation.
- In 1997, Finland shifted some of its revenue from personal income taxes and employer’s social security contributions to carbon and landfill taxes. Finland was the first European country to explicitly introduce a carbon tax. There are proposals to further increase the CO_2 tax by 25 percent. Road vehicle fuel usage would be exempt from this increase.
- In 1999, Italy introduced new carbon levies while reducing various employment-related levies. A year earlier, Italy had introduced NOx and SO_2 levies. These do not apply to road fuel users, but primarily to large fixed installations. The revenue from these two levies has been earmarked for environmental abatement programs.
- In 1999/2000, Germany is in the process of shifting revenues from social security contributions (both employer and employee) to an energy tax.

- In 1999 France reduced the "tax wedge" on labour with a new General Tax on Polluting Activities.
- In 1999/2000, Switzerland is reducing the required contributions to health insurance in favour of a tax on VOC and sulphur emission.
- The United Kingdom is expected to introduce a Climate Change Levy in 2001/2002 while reducing employers' social security contributions. The Climate Change Levy would apply only to business use of energy. This levy is projected to reduce CO_2 emission by 2 megatonnes by 2010. The UK is also expected to reduce vehicle registration fees (VED) for vehicles with smaller engines and eventually to adopt a graduated VED system for new cars based primarily on their CO_2 emission.

For the most part, these shifts represent an average of 0.25 to 2.5 percent of total government tax revenues.

Vehicle taxes generate the second highest level of revenue of all environmental-related taxes in Europe. A number of the European states have revised or are in the process of revising the structure of their annual vehicle taxes by incorporating an environmental-related aspect into the tax base. New developments in the context of vehicle-related taxes are also being seen in respect to road pricing. This is discussed in a subsequent section.

5.1.2 The Danish Experience

The Danish experience with carbon taxes and other environmental levies is of particular interest.[28] Soo, et al. [1999] undertook an in-depth review of Denmark's second National Communication on Climate Change. Denmark was among the countries that in the late 1980s included climate change in its policy agenda. Since then, climate change policy

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28 A more detailed assessment of the Danish CO_2 tax can be found in Starzer, Schmid et al. [1998] who indicate that "… the CO_2 package can be characterised by:

- *The effective level of taxation is the highest in the world for industry.*
- *The total revenue from the tax is expected to be three billion DKK in year 2000 which is 1% of the total state revenue. The revenue is to be recycled mainly by lowering the non-wage costs of labour.*
- *The level of taxation depends on the purpose of the energy use. Three types of energy use are defined. When companies use the same energy source for different purposes, several meters are required within the company.*
- *Companies with energy-intensive processes get a tax reduction if they enter an individual agreement with the Danish Energy Agency. For these companies the economic instrument is combined with an administrative one."*

Starzer, Schmid et al. make no reference to transportation in their assessment and the European Environmental Agency's [2000] inventory of pollution taxes does not show the Danish CO_2 tax to be applicable to any form of transportation.

has been target-oriented. The national target called for a 20 percent reduction in energy-related CO_2 emissions in 2005, compared to their 1988 level. Danish climate policy centred on the extensive use of economic instruments.

Soo reported that, by implementing an aggressive energy efficiency policy, Denmark has had remarkable success in decoupling energy demand from economic growth. The total final energy consumption (TFC) increased by only 3 percent between 1980 and 1995 while GDP grew by 40 percent, reflecting a level of energy intensity that is among the lowest of countries in the OECD. Transportation emission has also been slowed down, however the **net** gains in transportation have not been as expected. Between 1990 and 1995, CO_2 emission from transportation increased by 12 percent, compared to 40 percent for the Danish economy as a whole [Soo, Table 1].

1990 Transport Action Plan

Transport policy in Denmark had been founded on the 1990 Transport Action Plan set the target for the transport sector to contribute to the 2005 reduction target by stabilizing emissions at the 1988 level. As noted above, recent developments indicated that this target would not be attained. In spite of the Government's attempt to control traffic expansion by keeping the taxes on car purchase at a high level compared to the other EC countries, Soo noted that Denmark has experienced very strong growth in both car numbers and miles driven. Starting however, from a lower level than the other EC countries. Data available indicated that the growing number, and use, of cars offset fuel efficiency gains—presumably the result of economic growth—thus leading to an emissions growth.

Recently, Denmark noted that 1998 energy efficiency agreements with automakers would lead to higher-than-expected emissions from transport as the result of the growing use of cars. However, it was estimated that a further increase in gasoline prices would affect car use in Denmark as a one percent rise in fuel prices in the past induced a 0.6 percent improvement in car fuel economy.

Changes in Fuel and Vehicle Taxation

Another recent development in this sector was the 1997 parliamentary decision to introduce changes in the taxation of fuels and vehicles including:

- the change from a weight basis to a fuel consumption basis for the yearly tax on vehicles;
- differentiation of the tax on gasoline depending on its benzene content;
- the provision of incentives for light commercial vehicles to meet the proposed EC standards and the intention to extend this incentive to passenger cars.

At the same time, Danish officials told the Soo group that implementing stricter measures in the transport sector may prove difficult, given the long time required for car stock replacement and given hat raising fuel taxes unilaterally would result in extensive cross-border trade in gasoline.

Other Danish Approaches to Transportation

Denmark has also recently planned or implemented several large infrastructure projects to improve public transport. Moreover, the public transport price dropped by 10 percent in 1997, thus creating an incentive for more extensive use. In addition, Denmark has embarked on a series of smaller pilot projects in the transportation area with funding and encouragement of the Environmental Protection Agency. The following examples have been drawn from the *Danish EPA News Summaries* [Denmark EPA, 1999 and 2000].

> **Commuting plans** have been established as part of a pilot project at the Danish Labour Market Supplementary Pension Scheme (ATP) in Hillerød. The objective of the plan was to present employees with offers that can make commuting more environmentally friendly. Methods to achieve this included encouraging the use of bicycles, public transport and car-pooling. Commuting plans were identified as a means by which local authorities could assist in "reversing the trend towards a growing traffic load" especially since travel to and from work accounts for a third of all vehicle traffic in the area. Initial surveys and evaluations found that employees and employers were interested in commuting plans and that travel time, health costs and environmental considerations are significant factors. As a result of the pilot project, authorities in Hillerød have established a Commuting Office to assist other companies and have set up a carpooling database.
>
> The EPA examined the establishment of **Urban Environmental Zones** in inner city areas where special regulations apply for vehicular traffic. These zones are established to reduce environmental impact of transportation. The EPA noted that most of the measures designed to address environmental issues–generally requirements regarding catalytic converters and fuels—are aimed at transportation in general, but that traffic-induced environmental damage is more pronounced in the cities where traffic and populations are more dense. In April 2000, the Danish Parliament introduced changes in the Road Traffic Act to empower local and county councils to study and establish environmental zones. Four concepts were examined in relation to environmental zones:
>
> - *Environmental classification of vehicles* which implies that vehicles may not be allowed within a particular zone unless they meet specific environmental

requirements. The EPA estimates that the concept will half emission of particulates and NOx. Even greater reductions of hydrocarbon are expected.[29]

- *Regulation of traffic of goods and lorries* is seen as having potential that this type of traffic represents a large share of the environmental pressure in central urban areas. Some cities have introduced weights and dimensions regulations. Other options include improvements in loading and unloading and a requirement for a capacity utilization of at least 60 percent for transportation to and from the zone. It is expected that the concept will lead to reduction in total freight traffic as well as a reduction in NOx and particulate emissions.

- *Regulation of car traffic* is seen as an important means of addressing environmental concerns. The EPA reported that Copenhagen abolished 10 percent of the parking spaces in the city centre and that these are now limited to 12,000 spots. It is estimated that further reductions in parking availability, increased parking rates, plus allowing a 50 percent discount for cars with three or more occupants will reduce traffic in the environmental zone by 10 to 15 percent. These estimates presuppose the establishment of additional "park and ride" facilities on the outskirts of the city and increased participation in the development of commuter plans by large companies.

- *Improvement of diesel-powered vehicles* as a means of reducing environmental damage is based on the fact that the critical emissions in urban areas consist of particulates and NO_2. It is proposed that only vehicles with catalytic converters and particulate filters be allowed in environmental zones. The EPA forecasts that such a concept would halve particulate emission.[30]

Car Pooling and Sharing has been extensively examined in Jutland. In the village of Humlum the Struer municipality, 10 percent of households expressed interest in a car-sharing scheme while a study at four major businesses in Northwest Jutland showed that 23 percent of the staff are interested in organized car-pooling. Seven percent of the employees already participate in car-pooling. As a result of this initial effort, the transport office in Struer has become involved in additional car sharing schemes. Additional car sharing stations are to be established in northwest Jutland in the next few years. The EPA indicates that

29 This is attributed to the requirement for catalytic converters on petrol-powered vehicles. The EPA's wording suggests that the incidence of catalytic converters in Denmark may not be as advanced as it is in North America. This is also supported by the apparent higher use of leaded gasoline. In part, this may be due to a greater stock of older vehicles.

30 It was noted that regulations must be established so as to avoid any apparent discrimination based on nationality. This means that motorists from other countries must have the same possibilities of meeting the standards as Danes. We note similar concerns with respect to environmental proposals from other EU countries.

total mobilized transport decreases when households participate in car sharing. A decrease on the order of 20 to 30 percent in rural areas and even more than major towns have been suggested. This level of reduction, however, is tied to access to other forms of transportation such as public transit and car-pooling.

Results of Danish Initiatives are Not Known

In general, there was a wide range of traffic and environmental action plans developed in Denmark during the mid-1990s. The EPA reports the expenditure of some 150 DKK for the development of action plans in 50 municipalities and the establishment of some 136 specific projects. Overall the EPA reports that the "documented environmental effects are somewhat unsatisfactory, although this should not be taken as an indication that the actual results of the Programme are unsatisfactory." The main problem is that it has not been possible to document the environmental impacts due to "inadequate data available," and the EPA's evaluation recommends that future efforts should encompass procedures and methods for data collection. The lack of data—especially cost data—on transportation-related environmental projects and initiatives has also been noted in an EC evaluation of GHG reduction in Denmark. We note that further detailed project descriptions are referenced as being available from the Danish EPA; however, non of these reports actually appear to be available.[31]

A common thread through many of the Danish initiatives appears to be a reliance on measures a mix of measures, not just economic instruments. Clearly the reduction of parking through higher fees and the offering of reductions in parking fees for multiple-occupant vehicles are economic instruments. In the Copenhagen case, however, much of the control of parking has taken the form of government acquisition and elimination of parking spaces. Although not stated, it would appear that Denmark has limited its some of its use of economic instruments to non-transportation activities. Nevertheless the Danes appear to be in the forefront of the use of economic instruments [Danish EPA, 1998] and the European Environmental Agency's [2000] evaluation indicates that Denmark levies significant transport-related taxes. Denmark also makes extensive use of awareness building and voluntary agreements.

5.1.3 Carbon Taxes

Carbon taxes have been examined in more detail by the OECD [Baron, 1997]. For those European countries which have introduced such taxes (Denmark, Finland, the Netherlands, Norway and Sweden). Baron offered the following general comments:

[31] This may be due to a restructuring of the EPA's website and possibly to a move to converting these documents into "priced documents". The EC evaluation also notes that a number of the referenced documents have yet to be translated into English.

- none of the implemented schemes covers all energy uses resulting in CO_2 emissions in a completely homogenous fashion, either on a per unit of energy or per tonne of CO_2 basis;
- exemptions and exceptions have been granted to energy-intensive industries or to industries facing acute international competition; electricity, a highly traded commodity, is also granted special treatment,
- carbon/energy taxes are sometimes introduced in place of other taxes on energy, so as to minimize the additional fiscal pressure, while providing a proper signal to reduce CO_2 emissions;
- countries rely on taxes as *one* policy measure *in a package* of measures to achieve their emissions objectives; this accounts for differences among types of energy-users more than would be the case for a uniform tax;
- carbon/energy taxes are often part of a more general fiscal reform to solve structural fiscal issues such as high "distortionary" taxes on employment and capital.
- taxes are usually phased-in, providing a period of adaptation and avoiding the negative effect of a "price shock". Tax rates can be adjusted for inflation over time to keep the signal constant in real terms.

Baron did not report on any specific transportation impacts of the introduction of carbon taxes in these five countries.

5.1.4 Differentiated Fees

There is a movement to externality-differentiated fees in Europe. Sweden's environmentally differentiated waterway and landing fees for the air and marine sectors have been noted earlier. For aircraft, addition to landing charges for emissions depends on aircraft engine pollution of hydrocarbons (HC) and NOx.[32] The average value during the landing and take-off (LTO) cycle comes from the ICAO Engine Exhaust Emissions Data Bank. Classification is made into seven classes. To be classified in class 1 to 6, the aircraft's engine emissions of HC has to be less than 19g/kN and NOx less than 80g/kN. The best aircraft engines (according to emissions) are in class 6. The increased charge for emissions is from zero to 30% of the value of the landing charge (see Table 20).

Kågeson [1999] reports the status of differentiated maritime fees in Sweden. The Swedish Maritime Administration, the Swedish Port and Stevedores Association and the

[32] Emissions related landing charges are applicable to aircraft exceeding 9 tons maximum take-off weight and to airports with more than 300 000 passengers or 30 000 tons cargo a year.

Swedish Shipowners™ Association in 1996 arrived at a Tripartite Agreement to use differentiated fairway and harbour dues to reduce emissions of NOx and sulphur by 75 percent within five years. The parties concluded that vessels engaged in dedicated trade and other frequent vessel traffic involving Swedish ports, regardless of flag, should reduce emissions of nitrogen oxides by installing selective catalytic reduction (SCR) or other cost-effective NOx -abating techniques.

Table 20: Sweden's Emissions-Differentiated Airport Landing Charges.

Class	Average value of emissions During LTO cycle	Percentage increase of landing charges
0	>19g/kN HC or > 80 g/kN NOx	30
1	<19g/kN HC and < 80g/kN NOx	25
2	<19g/kN HC and < 70g/kN NOx	20
3	<19g/kN HC and < 60g/kN NOx	15
4	<19g/kN HC and < 50g/kN NOx	10
5	<19g/kN HC and < 40g/kN NOx	5
6	<19g/kN HC and < 30g/kN NOx	0

The Swedish fairway dues consist of two parts, one related to the gross tonnage of the ship and one based on the amount of cargo. It is only the former that is differentiated according to environmental criteria. The ship-related dues used to be SEK3.90 per gross tonne (GT) for oil tankers and SEK3.60 per GT for ferries and other ships. From 1 January 1998, when the new system was introduced, these basic levels were raised to SEK5.30 and 5.00 (C$0.85 and C$0.80) respectively to make room for substantial deductions for ships that emit less sulphur and nitrogen oxides.

More than 20 Swedish ports (of a total of 52) have introduced environmentally differentiated harbour dues. Each port is an autonomous body which, in competition with other ports, has to cover its costs. This makes the situation of ports different from that of the Maritime Administration. The challenge lies in differentiating the port dues in a way that provides an incentive additional to that of the fairway dues without risking a loss of customers or revenue. Such difficulties explain why the harbour dues are much less differentiated than the fairway dues. The sulphur-differentiated discounts/penalties (SEK/GT) of selected major Swedish ports are:

	Discount	Penalty
Port of Gothenburg		0.13
Port of Helsingborg	0.10	
Port of Malmö	0.10	
Port of Stockholm*	0.10	0.10

The port of Gothenburg raised the dues for ships running on high-sulphur fuels to SEK0.20/GT, (C$0.03) on 1 January 2000, while the ports of Helsingborg, Malmö and Stockholm offer a small discount for vessels that use low-sulphur bunker oils. The border between low and high sulphur content is set at 0.5 percent for ferries and 1.0 percent for other ships. Ten (October 1999) Swedish ports have also introduced discounts for low emissions of nitrogen oxides, but the discounts are fairly small compared to the nominated rates.

The European Union's implementation of the revised *Eurovignette Directive* represents a differential tax for heavy goods vehicles whereby the degree of emission is explicitly recognized in the level of a road usage charge.[33] Under the directive, the payment of road user charges in those countries without specific road tolls will change and the vehicle tax will be scaled according to the damage caused to the environment and road infrastructure. Heavy goods vehicles meeting the EURO-II (post 1996) and better, standard are thus charged less than EURO-I (1993) and worse, vehicles. Likewise, the least heavy vehicles pay less. The EU forecasts that "… the new scheme will build 'external costs' into the calculation of the rate, not just the internal costs normally borne by the vehicle owner. In this way the new Eurovignette directive translates into practice one of the priorities of the EU's transport policy, namely fair pricing."

The new directive, which took effect 1 July 2000, applies to vehicle taxes, tolls and charges for use payable by heavy goods vehicles with annual charges ranging from ECU 750 (C$1,000) for 3-axle trucks meeting Euro-II emission standards, to ECU 1,550 (C$2,077) for 4-axle trucks at Euro-0 (prior to 1993) emission standards.

There are exceptions to the Eurovignette charge. A fifty percent reduction in rates is to be offered for the first two years to vehicles registered in Greece to reflect the "country's geopolitical position". Greece, Italy, Portugal and Spain are authorised to charge reduced rates of not less than 65 percent of the minimum. Greece and Italy should also be granted

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33 Since 1 January 1995 Member States had been allowed to impose road user charges, set at a maximum of 1250 ECU per vehicle per annum for heavy goods vehicles. The Member States which have introduced the charge (Germany, Denmark, Belgium, Netherlands and Luxembourg) apply it as a single regional charge (vignette) covering the whole of their territories, which avoids the need for payment of a separate charge when crossing from one country to another within that group. Subsequently, the European Court held that the Eurovignette had not been implemented correctly. Charges were maintained pending the negotiation of a new directive.

ecopoints[34] not used for transit by Austria. More importantly, Austria is authorized to levy tolls on the Brenner-Kufstein axis, one of the main trans-Alpine routes for heavy goods vehicles which has experienced major congestion for years.

We note that the issue of Alpine transportation lead to a " … protracted and fastidious [negotiation] procedure that has extended over almost three years." [European Report, June 1999]. Hitherto Switzerland has not allowed vehicles over 28 tonnes into the country. Given Switzerland's central location in the Alpine range, this meant that heavy goods vehicles have had to make a detour and cross at other particularly congested points, notably the Brenner Pass between Austria and Italy. It was estimated that the Swiss restrictions affected one million EU vehicles a year and forced them to drive an extra 80 million kilometres. Under the new agreement, Switzerland will allow heavier vehicles, but under a quota system with some additional charges. The EU intends that these quotas and heavy goods vehicle charges will balance out the spread of traffic between the Brenner route in Austria and the routes through Switzerland. For this reason Austria relinquished its insistence on a safeguard clause on Brenner crossings which had been part of the compromise proposal for the Eurovignette directive.

5.1.5 Noise Fees

Noise pollution charges have been levied at airports in Belgium, France, Germany, Japan, the Netherlands, Norway, and Switzerland. In Switzerland, planes are taxed from 0 to 400 SF (C$500) per take-off depending on their noise class [OECD, 1995b p.94]. In Germany, the percentage of aircraft conforming with stricter noise standards increased in the late 1980s, but it is unclear whether this increase was due to noise pollution charges [OECD, 1994 p.59].

5.2 Road Pricing Experience in the US, European and Other Countries[35]

Congestion pricing initiatives date back as early as 1975—Singapore through area licensing and registration fees and Hong Kong through electronic road pricing. Today there is considerably more experience to draw from, as well as several quite detailed plans that made considerable progress towards political approval. Small and Gómez-

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[34] The *ecopoints* system resulted from a 1992 agreement with Austria to reduce NOx levels from heavy goods vehicles transiting Austria. An ecopoint was equivalent to one unit of NOx emission and each vehicle was charged on the basis of its emission levels. The available ecopoints were distributed among the various countries and the European Union, but the total number of available ecopoints was to be reduced each year until the target of a 60 percent emission reduction was achieved.

[35] Much of this discussion is taken from Small and Gómez-Ibáñez's paper in Button and Verhoef, 1998.

Ibáñez (1998) summarize 13 such cases, including Singapore, and draw lessons about implementation for them. The cases are divided into four broad categories:

1. congestion pricing of a centre city,
2. centre-city toll rings designed primarily to raise revenue,
3. congestion pricing of a single facility, and
4. comprehensive area-wide congestion pricing.

Table 21 lists the cases according to these categories, and shows whether each case is already implemented is under study or, as in one case, is a limited-time experiment.

Table 21: Cases of Road Pricing Reviewed

Type of Road pricing	Degree of Implementation		
	In place (starting date)	**Experiment (dates)**	**Under Study**
City centre: Congestion pricing	Singapore (1975)		Hong Kong Cambridge, U.K.
City Centre: Toll ring	Bergen (1968) Oslo (1990) Trondheim (1991)	Stuttgart (1994-95)	Stockholm
Single facility: Congestion pricing	Autoroute A1, France (1992) State Route 91, California (1995) Interstate 15, San Diego (1996)		
Area-wide: Congestion pricing			Randstad London

Source: Small and Gómez-Ibáñez (1998)

5.2.1 Singapore's Area License Scheme (ALS)

Singapore's ALS is part of an extremely stringent set of policies designed to restrict automobile ownership and use in this crowded island city-state of three million people. Toh [1977] indicates that the ALS was the fourth of a four-pronged approach that included a curbing of car ownership by increasing the purchase and ownership costs of motor vehicles through tariffs, steps to improve public transportation in an effort to encourage its use, and traffic management measures to relieve congestion. Another policy tool adopted by the Singapore government in 1990 is a *Certificate of Entitlement*, which is a form of tradable permit that we discuss later in this chapter.

The national government chose the ALS over conventional road tolls and higher parking charges because space for toll stations was lacking in the city centre. It thought that higher parking charges would be ineffective in the face of heavy through traffic and numerous chauffeur-driven cars. Under ALS, company cars were charged twice the residential rate for a license,[36] while buses, service and military vehicles, carpools (with four or more people) commercial trucks and taxis were exempt and could move freely within the CBD without a license.[37]

ALS collection costs have been modest, (amounting to about 11 percent of revenue in the early years) and was extremely successful in reducing traffic congestion during the peak hours. The planning target was to reduce the use of roads in the CBD and curtail peak hour traffic by 25 to 30%. According to Toh, by the fourth week of ALS:

- traffic flow during the peak hours had fallen by 45.3%,
- the number if cars in the CBD was reduced by 76.2%,
- carpools increased from 12.7% of the vehicles to 30.2% (a 96.9% market share increase),
- the percentage of commuters travelling by bus increased from 35.9% to 43.9%.

The restrictions were initially applied to the morning peak and expected to lead to a "mirror image" reduction in the evening return hours. In 1989, in an effort to strengthen the results of the ALS, the Singaporian government modified the program. The restricted hours were lengthened to include the afternoon rush hours of 4:30 to 7:00 (later shortened to 6:30). Furthermore, car-pools, private and school buses, commercial vehicles, and motorcycles were taken off the exempt list [Toh, 1992]. In 1994, the hours were extended to include the time between the morning and afternoon peaks. In 1994 the ALS was extended to a two-tiered structure covering a longer period of the day, with one charge for a weekday permit valid for the midday hours (10:15-16:30) and a higher charge for a permit that also covers the morning and afternoon peak (valid 7:30-18:30). In March 1998, the current paper permit system was replaced by an electronic 'smart card' system.

The other policy measures adopted by the Singapore government have also contributed to reduced congestion and emissions. The other measures presently in place include:

- a quota based marketable Certificate of Entitlement (discussed later),
- annual license fees that escalate with the size of the engine and incur surcharges for vehicles older than 10 years (from 10% at 10-years, to 50% at 14 years and older),

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36 The base fee has ranged from approximately Cdn$2.25 to $3.75 per day.

37 Taxis exemptions were lifted very soon after the introduction of the program. Truck (whose peak period use increased by 124%) had exemptions lifted in 1989.

- initial registration surcharge that is presently (November, 2000) set at 140% of assessed market value of the vehicle,
- a set of rebates for ownership of vehicles restricted to off-peak usage.

Singapore's vehicle quota system (discussed later under tradable permits) which was introduced in 1990, along with the other pricing measures noted above are credited with significantly limiting the number of vehicles in Singapore. Anderson and Lohof [1997] report that without vehicle ownership and use disincentives the number of vehicles in Singapore would have been 400,000 by 1992 instead of the actual number of 274,000.

While the ALS has proven to be an effective economic instrument in reducing congestion, it is not clear that the fee is an economically efficient one. In 1990 a study by the Public Works Department in Singapore found that, in fact, the average speed in the restricted zone during the peak period was faster than during the non-peak periods [McCarthy and Tay, 1993]. Many—Watson and Holland [1978], Wilson [1988], Toh [1992], and McCarthy and Tay [1993]—argue that the fee is too high. Small and Gomez-Ibanez [1998] indicate that spillover across spatial and time boundaries may make this scheme too crude an approximation of marginal-cost pricing to provoke the net economic benefits achievable in theory.

5.2.2 Lessons learned from other attempts

The Hong Kong and Cambridge systems might each be described as technical successes but political failures. Hong Kong evaluated electronic time-of-day tolls between 1983 and 1985. Hau [1991] reports that the technology exceeded the goals for reliability and ease of use. More than 99.7% of vehicles crossing toll points were correctly identified and wrong vehicle charges occurred less than once in 10 million. However, the experiment did not lead to implementation because of complex political factors including people's fear of government intrusion and association of the system with the British governor.

In the system proposed for Cambridge, real-time pricing was to be implemented by means of an in-vehicle meter containing a clock and connected to the car's odometer. Pricing schemes could be tied to congestion impacts of slow speed and stop-and-go activity. Charges would be deducted from the balance contained in a prepaid 'smart card' or 'electronic purse', thereby preserving the user's anonymity and overcoming one source of resistance encountered in Hong Kong.

From the users point of view, real-time charging would have meant that on those very days when travel conditions were unexpectedly poor, a financial penalty would be added to the aggravation already experienced. Many citizens might blame politicians or traffic planners for incidents of severe congestion rather than accepting the principle that they should pay more because they are imposing higher marginal costs on others. Surveys in the summer of 1994 found that the road pricing concept was viewed as 'acceptable' by only one-third of respondents, a larger proportion than for cars bans or parking controls but far less than for public transport improvements. In addition, it was perceived that drivers might drive unsafely to avoid triggering the meter [Ison, 1996].

Small and Gómez-Ibáñez conclude that:

> *Cambridge demonstrated the technical feasibility of more sophisticated forms of road pricing. But it also demonstrated the need to develop grass roots support simultaneously with concrete proposals, especially ones as radical as the original Cambridge plan. It seems unlikely that any locality would accept a pricing scheme with unpredictable charges, at least in the absence of lengthy prior experience with less elaborate schemes.*

5.2.3 The Scandinavian Toll Rings

The Scandinavian toll rings do not represent congestion pricing. They are designed primarily to generate revenue to finance desired transportation infrastructure improvements. Congestion management is not among the objectives in Norway, and was only secondary in Sweden. Furthermore, the locations of toll stations were chosen not to optimize traffic management, but to achieve a politically acceptable balance between the financial contributions of city and suburban residents while altering trip-making behaviour as a little as possible. The Scandinavian toll rings may evolve into a system of congestion pricing, despite their modest beginnings. Two of the three Norwegian toll rings offer electronic toll collection as an option. The Swedish program has stressed environmental problems associated with traffic, especially in inner cities. The system was to allow fees to be varied by time of day and by type of emission control on the vehicle [Social Democratic Party et al., 1991, p. 30]. It was eventually to operate in a free-flow multilane environment with video enforcement, and to permit a single smart card to pay for the toll ring, public transport, and parking. Construction of the inner ring road and imposition of the toll ring were originally scheduled for 1997, but were subsequently delayed indefinitely. Public opposition to part of the inner-ring construction proved so severe that the entire agreement is in jeopardy. [Small et al. 1998]

5.2.4 Congestion Pricing of a Single Facility

Three examples of congestion pricing appeared during the 1990s. In each case, the operator of a crowded expressway has adopted an innovative tolling scheme for a particular limited purpose.

Autoroute A1 in Northern France: Weekend Peak Spreading

Autoroute A1 is an expressway connecting Paris to Lille, about 200km to the north. It is part of a network of toll expressways operated by the Societe des Autoroutes du Nord et de l'Est de la France (SANEF), one of the seven government-owned but quasi-commercial toll road operators. The A1 is subject to heavy inbound traffic peaking near Paris on Sunday afternoons and evenings. In April 1992, after a period of extensive public consultations and publicity, SANEF confronted this congestion problem by implementing time-varying toll schemes for Sundays only. A special 'red tariff' is charged during the Sunday peak period (16:30-10:30), with toll rates 25 to 56 percent higher than the normal toll. The hours and rates were designed so that total revenues are nearly identical to those collected with the normal tariff. This property was believed essential for public acceptance, which in fact has been largely favourable.

The impact of the scheme is mainly on the timing of trips. Comparisons of traffic counts show that southbound traffic at the mainline toll barrier near Paris declined approximately 4 percent during the red period and rose approximately 7 percent during the green period, relative to a six-year trend for comparable Sundays. The most pronounced shift was from the last hour of the red period to the later green period. A survey in November 1992 confirmed that many people – about one-fifth of those travelling during the green period – sought to lower their toll by shifting the timing of their trips, sometimes by stopping for meals at service areas along the highway (Centre d'Etude Techniques de l'Equipement Nord-Picardie, 1993).

The experiment on Autoroute A1 appears to be successful, and is being imitated by a fully private toll road company, Confiroute, at other tollbooths near Paris.

California's Toll Auction Lanes (State Route 91)[38]

The first site of congestion pricing in the United States is a section of highway (state route 91) in southern California, which opened to traffic in December 1995. Designed and operated by a private corporation, the project is far more complex than the Paris scheme. It is an extremely congested commuter route connecting the employment centres of Orange and Los Angeles counties with rapidly growing eastern suburbs, primarily in Riverside County. The scheme used by this project has come to be known as

38 Another HOT lane project, also in southern California, has been proceeding along a completely different path, essentially a scheme to sell off vacant capacity on the reversible lanes to single occupant vehicles, with the revenue targeted for public transit. The project has been proceeding in steps. Starting in December 1996, a limited number of monthly permits were sold at $50 each, the permit allowing unlimited use of the reversible lane during that month. Although a flat monthly fee may not appear to be congesting pricing, there is little incentive for anyone to purchase a permit except for use during peak hours. Thus the price of the monthly permit serves as a somewhat crudely targeted congestion toll.

'HOV buy-in' or high occupancy too (HOT) lanes [Feilging and Klein, 1993]. In essence, the unused capacity in HOV lanes is auctioned off to lower-occupancy vehicles. Some proponents of HOT lanes argue that one should later incorporate adjacent free lanes, one by one, into the HOT lane facility if there is adequate demand for faster service at a price.

The existence of three parallel lanes just a few feet away greatly constrains the tolls that can be charged on HOT lanes. As a result, the company operating the 91 express lanes uses a complex toll structure.[39] The price is announced on electronic message signs visible prior to the point where motorists must decide whether to opt for the priced or unpriced lanes. The project has received generally favourable ratings in opinion surveys, with 60-70 percent approving toll finance and 50-60 percent (up from 40-50 percent before it opened) approving time varying-tolls [Sullivan and Mastako, 1997].

For the longer term, the operator in considering toll rates that would vary in fine increments in response to real-time measurements of congestion levels. Information about delays on the free lanes would be added to the price information that is already provided on variable-message signs. The fact that users would know the price in advance is an important difference between and the real-time pricing plan proposed earlier in Cambridge [Small et al. 1998].

The company reported that over 75 000 users established prepaid accounts and received transponders during the first year of operation. Traffic in the express lanes has grown steadily and was about 26 000 per weekday after a year of operation, with about 20 percent consisting of exempt HOVs. Delays on the adjacent free lanes have diminished dramatically, often to about 10-20 minutes. One would expect this to release considerable latent demand for the corridor, either through newly generated traffic or diversions from parallel routes. Preliminary findings of a monitoring study showed few such demand effects during the first six months of operation [Sullivan and Mastako, 1997].

U.S. Congestion Pricing Pilot Program

Lee County Florida is representative of one of the three congestion pricing pilot projects implemented in the United States. The Variable Pricing Program (formerly called Congestion Pricing Program) is one of ten federally funded grant projects (three are

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39 The toll schedule was revised in January 1997, primarily by raising the toll by $0.25 to $2.75 during the peak and night periods while leaving the shoulder of the peak the same, thereby creating a slightly steeper gradient. At the same time an optional two-part tariff was introduced, by which a flat fee of $15 per month entitles the user to a $0.50 reduction on every toll. Later revisions raised tolls further and introduced some toll variation within the four-hour peak periods.

implementation projects, seven are feasibility studies and one is a monitoring and evaluating study)[40] to study ways to reduce congestion on the nation's roadways. These grants were originally funded by the Intermodal Transportation Efficiency Act (ISTEA), and funding was continued under the Transportation Equity Act for the 21st Century (TEA 21).[41]

The Lee County Variable Pricing grant is a three party agreement with the Federal Highway Administration (FHWA) paying $16 million and the Florida Department of Transportation (FDOT) and Lee County each matching $2 million. The pilot project involved variable-rate electronic tolls for trips across two Lee County bridges providing access the central business district of Fort Meyers.

We note that the program emphasizes congestion rather than emission reduction by offering lower tolls during off-peak periods rather than increasing tolls during the peak period. The Variable Pricing hours are Monday through Friday, 6:30 a.m. to 7:00 a.m., 9:00 a.m. to 11:00 a.m., 2:00 p.m. to 4:00 p.m., and 6:30 p.m. to 7:00 p.m. During these times the toll is half price (twenty-five U.S. cents rather than the normal fifty cents per passage). The federal funding includes a $6.3 million Revenue Reserve Fund to reimburse Lee County for the loss in toll revenues caused by Variable Pricing. Under the current agreement, monies not needed for reimbursement of toll losses will be turned over for use on other projects in Lee County.

The effectiveness of the program has been monitored by charting the shifts of pre-paid patrons (who are eligible for variable pricing) relative to a control group of pay-per-use patrons (who are ineligible). For the period August 3, 1998 through December 31, 1998 (the first five months) toll losses of US$127,779 accrued to Variable Pricing. There were 477,769 trips during this five-month time frame in the Variable Pricing discount times. The traffic shifts for this same period ranged from about 17%-and-20% increases during the 6:30-7:00 and variable period shifts. The time-shifts for eligible travellers over one of the toll bridges are illustrated in Figure 3. The same bridge saw an increase in peak-period travel by non-eligible patrons, presumably due to the reduced congestion resulting from the shift away from the peak by other patrons.

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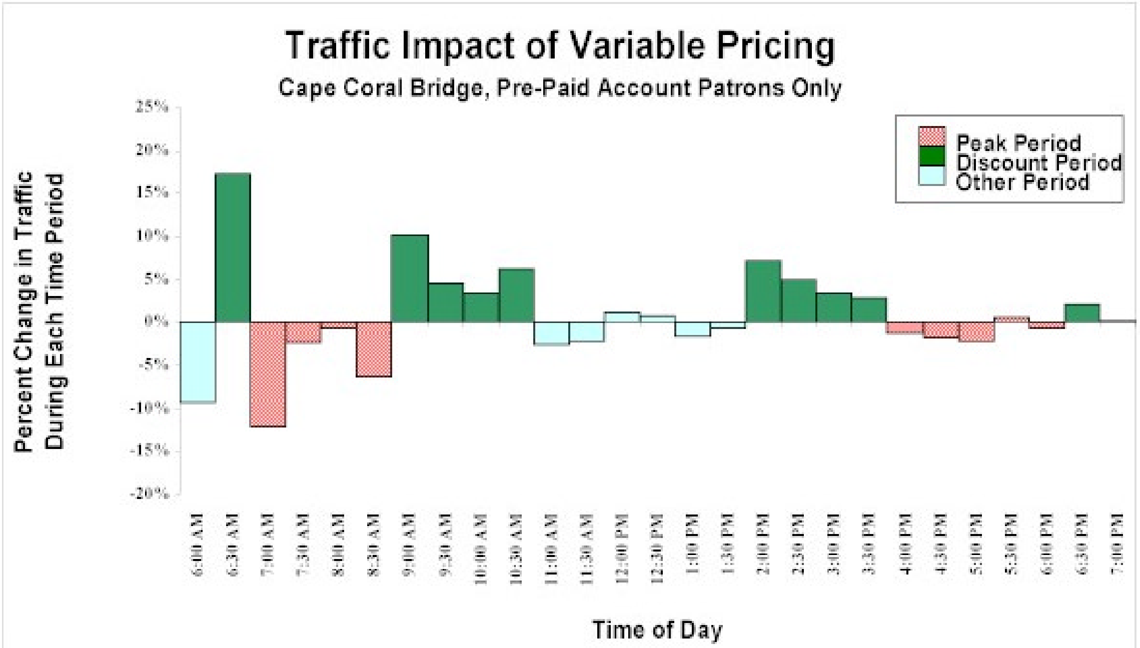
40 The ISTEA Congestion/Variable/ Value Pricing Pilot Programs that are currently being pursued include three implementation projects in Lee County, Florida; San Diego, California; and Houston, Texas; as well as six pre-project, or feasibility, studies in Portland, Oregon; Los Angeles, California; San Francisco and Sonoma County, California; Boulder, Colorado; Minneapolis/St. Paul, Minnesota; and Westchester County, New York.

41 The ISTEA provided funding of up to US$25 million annually over the 1992-97 period to support Federal participation in up to 80 percent of the development, start-up and operating costs of pilot projects.

Figure 3: Traffic Shift Illustration for Variable Pricing In Fort Meyers, Fl.



Source: Lee County web site (www.Leegov.com)

Another of the approved projects in California, thus far held up by environmental and financial considerations, would extend State Route 57 as an all-new elevated expressway along the Santa Ana River channel in Orange County. Eighteen kilometres in length, it would charge tolls tentatively proposed to vary between $1 at night and $5 during the peak. Initial planning for congestion pricing on the San Francisco Bay Bridge was overturned by political opposition, as was the far-reaching HOT lane proposal for the Seattle area mentioned earlier. [Small et al. 1998].

Small and Gómez-Ibáñez[1998] conclude that:

> *Both studies and actual experience have shown that congestion pricing can substantially affect behavior and reduce traffic congestion. At the risk of over-generalizing, it appears that charges of $2 to $3 per day for entry to a restricted area during peak periods can reduce traffic by 20 percent or more. Charges can be targeted to divert traffic around certain areas or to shift it from one time period to another. In most cases it is feasible to offer customers a choice of collection options. Operating costs can be kept to reasonable levels, around 10-12 percent of revenues.*

5.3 Tradable Permits

5.3.1 Singapore's vehicle quota system

In 1990, Singapore implemented a quota scheme to regulate the growth of vehicle population. Under this system, the number of new vehicles allowed for registration is pre-determined annually, taking into account the prevailing traffic conditions and the number of vehicles taken off the roads permanently, while the market determines the price of owning a vehicle. Under the system vehicle owners are required to have Certificates of Entitlement (COEs). COEs are valid for ten years and can be obtained in public auctions held monthly by the Registry of Vehicles. Owners of vehicles more than ten years old are required to pay the prevailing quota price. The COE requirement enables the government to determine the total number of vehicles in circulation based on the country's road capacity. COE prices have varied with market demand: for cars with a capacity over 2,000 cc, they have risen from about C$500 when they were introduced in 1990 to C$17,600 in 1992 to over C$100,000 in 1994. The November, 2000 auction values were about $35,000 for a passenger car of engine size greater than 1,600 c.c.

5.3.2 U.S. Initiatives

Tradable permits have been used in the U.S., mostly involving large industries with dispersed pollutants. Bearden [1999] notes that while early trading programs were based mostly on credits, allowance programs with emissions caps have become more common. Although exact savings are difficult to estimate, recent experiences with allowance trading under the federal acid rain program and in California's efforts to control ozone in the Los Angeles area indicate that these programs likely have reduced overall emissions at lower costs than conventional regulation. Whether an allowance program to control ozone transport in 12 north-eastern and mid-Atlantic states, which began in May 1999, will achieve similar results depends in part on the co-operation of the states involved. Bearden’s [1999] and Parker’s [2000] assessment of California’s Regional Clean Air Incentives Program follows.[42]

> ***Regional Clean Air Incentives Market.*** *In January 1994, California's South Coast Air Quality Management District introduced the Regional Clean Air Incentives Market (RECLAIM) in the Los Angeles area. RECLAIM is an allowance program aimed at reducing emissions of NOx and SOx The program's goal is to achieve an 80% reduction in emissions by 2003. Stationary sources that annually emit at least 4 tons of NOx or SOx receive allowances, which are based on past peak production and existing emission requirements. The total number of allowances is equal to the cap on emissions. The state reports that actual emissions have been below the cap each year from 1994 to l997. However, some critics argue that actual reductions in emissions have been less dramatic than a comparison to the cap suggests because emission allowances were initially high.* [Bearden, 1999]

Anderson et al. [1997] summarize the results of 28 different theoretical studies that compare incentive mechanisms with command and control approaches for managing the

[42] See the same author’s for discussion of the U.S. Federal Acid Rain Program.

environment. In every case the command and control approach was found to be more costly than the market-based approach. The cost ratios of command-and-control regulations to market approaches (most of which were trading schemes) varied from a low of 1.07 to a high of 22. "Of course, these are merely theoretical studies of *potential* savings. … available evidence points to relatively modest savings."

In searching for reasons for the wide gap between the potential and what actually is accomplished, Stavins identifies transaction costs as the primary culprit. With transaction costs as a barrier to trading, sources tend not to venture far from their initial allocation of pollution rights. As transaction costs rise, the prices that sellers receive for pollution rights fall and the prices that buyers must pay rise, making transactions less likely. Transaction costs were especially high in EPS's early Emissions Trading Program, described later in this report, with the result that less than one percent of the emissions potentially available for trading actually were traded [Hahn, 1989]. Transaction costs were lower for programs such as lead credit trading, resulting in a far higher proportion of available credits actually being traded. Transaction costs also feature prominently in the choice between making trades internally within a firm and externally between firms. For all of the trading programs that have been studied, firms exhibit a strong preference for internal trading when that is feasible, often even when larger cost savings are available externally.[Burtraw, Kerr]

Transport Initiatives
U.S. policy discussions of interest to transportation include using tradable permits to provide more flexibility to emissions regulations for engines and fuels, and a pilot project to test the feasibility of using emissions trading to encourage telecommuting. Each is discussed briefly below [Parker, 2000]:

> *On May 13, 1999, EPA proposed more stringent Tier 2 emission standards for new motor vehicles. The standards would be phased in between 2004 and 2009 and require vehicle manufacturers to reduce NO_x emissions by roughly 90% below levels currently required under the* Clean Air Act*. Manufacturers with NO_x fleet emission averages below 0.07 grams/mile would receive credits that could be used in later years or sold to other manufacturers having difficulty in meeting the standards. Under EPA's proposal, oil refineries also would be required to reduce gasoline sulfur levels to an average of 30 parts per million beginning in 2004. Refineries producing average sulfur levels below this amount would receive credits that could be banked for future use or sold to other refineries facing high costs to achieve compliance.*

> *U.S. legislation has been introduced that would encourage the use of emissions trading to promote telecommuting as a measure to reduce traffic congestion and control vehicular pollution. Specifically, the bill would authorize $250,000 in FY2000 for awarding a grant to the National Environmental Policy Institute (a nonprofit organization) to design*

> *a pilot trading program in conjunction with the Department of Transportation, Department of Energy, and EPA. The objective of the pilot program would be to test the feasibility of awarding tradable credits for emission reductions attributed to telecommuting. The amount of the credits would be based on the extent to which the decline in the number of vehicle miles traveled reduces emissions. Regulated entities would be able to purchase such credits to assist them in complying with* Clean Air Act *requirements. The pilot program would be tested in five metropolitan areas with high levels of traffic congestion and poor air quality, including Los Angeles, California, and the District of Columbia.*

Permit programs that have been in existence long enough to have had some evaluations include the U.S. leaded gas phasedown program discussed below.

U.S. Leaded gas Phasedown

Nussbaum [1992] examined the United States Lead Phasedown Program designed to reduce the volume of lead in gasoline to less than one half of one percent of that in the year 1970. This process represented one of the first of the *bubble* policies which enabled an industry to meet environmental standards while "retaining some degree of flexibility" in their operations. Nussbaum points out that the regulations provided the refinery industry with incentives to optimally plan their operations without mandating the precise lead limit *for each and every gallon of gasoline.*

The *bubble* approach is one that "seeks to ensure that environmental exposure to some pollutant is reduced or controlled 'on the average'". This accepts some variability among emitters in terms of the magnitude of the pollution" as compared to the more traditional means of imposing a uniform maximum level of pollution for each emitter. Three advantages were proposed for the *bubble* approach:

- It allows the institution of a more stringent overall level of regulation than would be feasible for *each* emitter to meet. Such a level of regulation may be quite feasible for an industry as a whole.
- It is possible to improve the flexibility of a regulation from the standpoint of the regulated entities and thus lessen possible negative economic impacts.
- It may improve the "fairness" of the application of the regulatory burden especially in cases where some firms may be somehow unusually sensitive.

Nussbaum, however, cautions that such flexibility may "unintentionally reduce some of the environmental benefits." He cites the hypothetical case where a regulation permits the emission of five units of waste per day with significant consequences for exceeding this limit. Under such a scenario, a firm may avoid a large risk of non-compliance and take precautionary measures to ensure that only four units of waste are emitted. Were the regulations to be rewritten to allow temporal flexibility (say a maximum of 150 units of waste over a 30 day period), the firm may take less aggressive action and ensure that no more than 140 units of waste were emitted during a month. In Nussbaum's example, an additional 20 units of waste are emitted even though total emission remains under the standard.

Today (2000) the advantages of the flexibility of the *bubble* or similar approaches are more generally recognized. It must be remembered that the U.S. regulations for the reduction of lead were introduced nearly thirty years ago. At that time, flexibility in regulation was somewhat novel.

Lead provided an interesting example in the connection of the *bubble* approach with emission trading and banking. Lead compounds were first used in the 1920s to boost octane. Given diminishing marginal octane benefits from lead, refiners have an incentive to spread the amount of lead they use as evenly as possible over their total production of leaded gasoline. Prior to regulation, an average of about two grams per (leaded) gallon (glpg) was typical. In the early 1970s the push for reduction of lead began both as a means of improving health and as a means of providing increased availability of unleaded gasoline required for catalytic converters.

In the early days of the regulation of lead, quarterly averaging of lead concentrations (plus special standards for smaller refineries) was used, providing a compromise between environmental concerns and the industry's need for flexibility. A shift in emphasis took place with the regulations that became effective in late 1982 and early 1983. Nussbaum notes that the standard of regulation changed from one pertaining to a refinery's pooled output (leaded *and* unleaded) to one that applied only to leaded gasoline. Standards were also tightened and special "small refinery standards" were eliminated. At the same time, a trading system was adopted which provided for an improvement in the allocation of lead usage among refineries. Refineries which needed less lead than the amount allowed by the standard were permitted to sell their excess to other, less-technologically-advanced refineries.[43] A modern facility that could produce leaded gasoline with a concentration of 0.70 gplg could trade the difference between that concentration and the standard of 1.10 gplg to older facilities which found it necessary to use more than 1.10 gplg in their product. These transactions had to occur within the compliance period in question, but could occur across corporate boundaries.

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43 It was noted that the older refineries tended to be the less technologically advanced ones. These were generally located in the east. The newer facilities—often concentrated in the west—tended to be more technologically advanced.

Since trading agreements in the gasoline industry are commonplace, Nussbaum found that the additional trade of lead rights usually incurred no transaction costs and little more paperwork costs than "… the addition of a contractual paragraph and, perhaps, the price of a stamp."

There was a further tightening of the lead standards beginning in 1985. Allowable concentrations were reduced to 0.50 gplg on 1 July 1985 and to 0.10 gplg on 1 January 1986. Trading was continued and a provision was made for the banking of credits for the amount of lead that a refiner could have used but did not actually use. Accumulation of lead credits was allowed during 1985. These rights were available for use or transfer during 1986 and 1987, after which all remaining lead (trading and banking) rights expired. Thus, during the later stages of the much more stringent standards, a less efficient refinery could purchase rights from the more efficient refineries who had more than complied with the then existing standards.

Nussbaum's analysis of the US Environmental Protection Agency's (EPA) data shows that from the end of the third quarter of 1984 the average concentration of lead fell below the 1.10 gplg limit and was somewhat lower than the 0.50 gplg limit which came into force in the middle of 1985. Banking of credits was in force for most of this period. The average concentration continued to fall, but averaged 0.30 gplg when the standard was reduced to 0.10 gplg. The average lead concentration continued to decline slowly throughout 1986 and 1987.[44] Although he does not cite exact figures for what volume of lead rights were traded between firms[45], Nussbaum concludes that "*banking and trading together provided for an orderly adaptation by the more obsolete facilities, providing them with the time necessary to install new equipment*" while meeting a standard which public health needs required to be as stringent as possible.

There were some issues that arose or were feared from the trading/banking system. The trading provisions unintentionally permitted facilities blending alcohol into leaded gasoline to claim and sell lead rights. The activities of these blenders are reported to have only generated a small amount of lead rights. Nevertheless, Nussbaum cautions that "all else will not be equal" since regulations will cause some perturbations. There was also concern that trading might lead to "hot spots" or localities where very high concentrations of lead might occur. Nussbaum reports that the EPA's analysis considered

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44 Actual lead concentrations increased somewhat during the second quarter of 1986.

45 Starting in 1983, between one-fifth and one-third of reporting facilities indicated that it was "…either necessary or desirable to purchase lead rights…". It was reported that transactions accounted for approximately seven percent of total lead used in the early periods and as much as 20 percent by the end of 1984.

this possibility but determined that, at worst, the concentration of lead in the East might have reached 1.16 gplg during the period when the limit was 1.10.

One of the more important observations of the Lead Phasedown Program is the relationship between trading and banking. Initially, there was not a significant volume of trading in lead rights, which had to be used within the current quarter. Banking, however was heavily used from its outset. Nussbaum notes that many entities that regarded trading as a minor incentive found banking to be a major incentive. Along with banking came a sharp increase in trading. Nussbaum suggests that the lead rights—because they no longer expired at the end of each quarter—were worth more and were traded in more rational markets where sellers had more time to seek out buyers, and where brokers entered the market. Major refiners—who had previously not been motivated to trade lead rights—began to bank and trade aggressively, stockpiling rights for use during the transition to the more stringent standard.[46]

The overall assessment is that the banking and trading produced exactly the effect that they were intended to produce—trading off lower lead use than the standard in 1985 against higher use in later years, but with total use over the period being "…about the same as if the standards had been rigidly held to." Nussbaum speculates that the significant reduction in lead concentrations may not have been achieved had the *bubble* approach not been used. Whether or not this would have been the case, there is evidence that the standard was met with a greatly reduced economic impact. Nussbaum cites EPA studies suggesting that the initial trading allowance saved the refining industry $65 million while the latter banking/trading allowance saved some $200 million.

The lead trading/banking system was designed in such a way that the EPA would "…keep a low profile and let market mechanisms do most of the work." Nevertheless, Nussbaum reports that ensuring compliance involved more paperwork than was originally contemplated. He notes that since lead rights were valuable "…there was an incentive to cheat." Lead transactions in were in the range of one to two million dollars. Thus monitoring and enforcement became major issues since "…under banking and trading, the host of possible violations increased exponentially." Violations included trades that were not properly generated, selling the same rights twice and banking rights for a future period that were required for compliance in the current period.

46 Nussbaum also notes the increase in the number of alcohol blenders being linked to the higher price of lead rights, which rose from three-quarters of a cent to over four cents per gram.

Nevertheless, Nussbaum reports that the lead trading system fared “remarkably well”. “In the balance between some administrative nightmares for a few versus the marked environmental benefit for the many, the correct party ‘won’.”

Noting that again that the refinery industry was well versed in product trading and sales among the individual members, Nussbaum offers the following lessons learned from the US Lead Phasedown Program:

- An easily defined and easily measurable unit is required so that there can be no confusion concerning what is being traded or banked.
- A finite time period is required to avoid an open-ended arrangement, which results in a never-ending struggle to measure compliance.
- Good communications and training are required to avoid many of the enforcement headaches that stem from the inherent complexity of rules.
- Independent audits would go a long way to identifying problems quickly.
- In an endeavour to administer an equitable program and to close all the loopholes, it is possible to react too much.

5.4 Relevant Canadian Initiatives[47]

The traditional approach to road funding in Canada has been to treat roads as a public good and finance their construction and upkeep out of general tax revenues. Ministers of transportation in each province and territory compete with cabinet colleagues for a share of the revenues from a consolidated fund.

But this was not always the way roads were financed.[48] When fuel taxes and vehicle registration fees were first introduced, they were often treated as a specific tax on road users. Revenues were often earmarked for roads. Between the years 1924 and 1951, eight provinces had legislation linking gasoline tax revenues to road construction or maintenance. These practices died out after the Second World War and, indeed, even the practice of using tolls (usually bridges, but sometimes highways) almost disappeared during the 1960s. By the 1970s, Canadians almost universally regarded roads as a public good to be paid for by general tax revenues.

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47 Portions of this Section are from a forthcoming paper for the Transportation Association of Canada by Ray Barton and Fred Nix part of which is derived from an earlier paper: Nix, F.P. & J. Jones, 1995, *Highway Finance: Theory and Practice*, Transportation Association of Canada, Ottawa.

48 A full account of the early years of road taxes in Canada is available in Bryan, N, 1972, *More Taxes and More Traffic*. Canadian Tax Papers, No. 55, Canadian Tax Foundation, Toronto.

Since the 1950s, there have been 10 provincial or federal inquiries examining the way roads are financed. These have been evenly split on the subject of how explicit the tax system should be in making motorists pay for roads. The last one, the 1991/92 Royal Commission on National Passenger Transportation, was firmly in the camp of making road taxes explicit—that is, letting the motorist know that the taxes paid are specifically for the upkeep of the road.

The Royal Commission's impact on road finance and knowledge of full social costs is only slowly working its way through the various levels of government. Some important changes that have occurred over the past decade are noted at the end of this chapter. However, there has not been a significant change in the supply, operation and financing of roads. No department has been restructured as a crown corporation. Ottawa has not eliminated the excise tax on motor fuels (it has increased the tax rate). No province or territory has conducted a cost-allocation study to determine marginal road costs, although some general work has been done in Ontario, Québec and within Transport Canada. With the exceptions noted in the bullet list presented later, no government has seriously tried to charge motorists for externalities.

No government has admitted that any particular tax is really a price for using the roads. Finance Ministers tend to make a link between motorists and fuel taxes, particularly when they increase the tax rate. But, in a legislative sense, there is no direct connection between any tax and road use. The term "road-user tax" in Canada is a judgement call, not a legal distinction. A few qualifications are discussed below.

Finally, no weight-distance tax for trucks has been initiated.

A major factor in this lack of movement on internalizing the external costs of transportation is the lack of public acceptance. The high profile negative reaction to New Brunswick's toll highway and the avoidance of tax-based measures by the of the National Transportation Climate Change Table are indicators of this lack of acceptance. The strong reaction to British Columbia's recent discussion paper of a broad set of market-based initiatives for road users provides additional insight. The *National Po*st's coverage (December 2, 2000) included an interview with Norman Ruff, a political scientist at the University of Victoria with the following observation:

> *"SUVs don't vote, but their families do," said Prof. Ruff. "It is one thing to be green. It's another thing to have suicidal political tendencies."*

Nonetheless, there have been some important changes since the 1980s. Consider:

- Tax levels: Federal excise tax revenues on motor fuel, provincial and territorial fuel tax revenues and licensing revenues from motorists have all increased by about one-third since 1991/92 (the year the Royal Commission finished its work). In real terms—that is, adjusted for inflation—this is over a 20% increase in road-related taxes. Real road expenditures, on the other hand, have fallen by 10% or so over this period. Motorists are paying considerably more for roads (assuming these taxes are actually road prices) in comparison to the amount spent on roads than when the Royal Commission did its work.
- Tolls: In 1992 there were only three toll bridges and one toll road (Coquihalla) in Canada. In addition, there were a half dozen or so toll bridges and tunnels between Canada and the United States—but these were toll facilities primarily because of U.S. considerations on highway finance, not Canadian policy. Since the Royal Commission, the Confederation Bridge to Prince Edward Island has been built and new toll highways have appeared in Ontario (407)[49], Nova Scotia (Cobequid Pass section of 104), and New Brunswick. In this last case, New Brunswick has terminated tolls and replaced them with traffic volume related payments from the province to the road builder. There have been other recommendations for even more toll highways in Canada (e.g., a mid-peninsula highway in the Niagara region of Ontario).
- While toll facilities are now being used to add small links, a major network of toll freeways will probably not work in Canada. Traffic volumes of 10,000 to 15,000 vehicles a day may be required to make toll highways fully recover their construction and operating costs directly from the user. Only the busiest 12% of major highways—the 45,000 km connecting large population centres—have traffic volumes this high.[50] In addition, there may be political difficulties—a backlash from the public, such as recently experienced in New Brunswick—that make the extension of toll roads difficult.
- Involving the private sector: At least as significant as the fact that toll roads are once again being used to add road capacity is the manner in which these new roads were built. All of them were either financed or built with a greater degree of private-sector involvement than has traditionally been the case in Canada. One, Ontario's 407, was sold to the private sector after it was built. Public-private partnerships are being used

49 Highway 407 was an early technological leader in the use of electronic toll collection. It has a rudimentary time-of-day toll (night time is about ½ the day time price) and weight class differential fees (combination trucks pay roughly 3 times the auto toll). However, the toll system is tied to cost recovery rather than social cost factors.

50 The figure of 10-to15,000 vpd is from I. Heggie, "Commercially Managed Road Funds: Managing Roads Like a Business, Not Like A Bureaucracy," *Transportation* 26: 87-111, 1999. The calculation of roads with these volumes is based on figures given in: B. Leore, 1997, "The State of the Canadian Intercity Highway System, 1986-1993," *Proceedings*, CTRF annual meeting, Toronto.

in road projects other than toll roads. For example, several provinces (Ont, Alta, BC) have privatized aspects of road maintenance. In other case, bridges or roads have been built with "design-build" contracts. But, and whether tolls are involved or not, all of these arrangements transfer more responsibility for aspects of the road (operation, finance, design, etc) to the private sector. To this extent, they move the supply of roads more into the realm of commercial operations.

- Urban road-financing agencies: In three cities (Montreal, Vancouver, Victoria), agencies have been created that both collect certain dedicated taxes or other revenues and build or help finance urban transit and roads. The tax rates in cents per litre are as follows: 2.5¢ (Victoria), 4¢ (Vancouver) and 1.5¢ (Montreal). In other places—for example, Winnipeg—recommendations have been made to emulate these structures. In the case of GVRD and Victoria the funds are collected by the province and forwarded to the responsible authorities. In Vancouver's case the Greater Vancouver Transportation Authority (Translink) receives the funds from the provincial government and decides how they are spent. The province also provides an additional 4 cents per litre from its base fuel tax rates. The gas tax (8 cents per litre in total) accounts for about 30% of Translink's total budget. The other 70% is raised from such sources as property taxes, transit fares and a levy on hydro bills. The bulk of the agency's expenditures are on transit facilities. The tax in Victoria is strictly for expenditure on transit facilities
- In Calgary and Edmonton the provincial government has agreed to turn over a portion of the fuel tax revenues (5¢ per litre out of a total tax of 9¢ per litre) collected in the urban area so as to provide the cities with dedicated funding for transportation facilities. This generates about $80 million in annual funding for Calgary, $65 million for Edmonton. Each city has total discretion over how the funds are spent. The majority of the money is currently being spent on LRT facilities. Additional funding is available for each city from the provincial transportation budget.
- Provincial trust funds: Several provinces have established trust funds or have made tentative steps in the direction of dedicating taxes to roads. Other than in the case of British Columbia (see below) and the few urban areas mentioned above, these tentative moves towards trust funds and dedicated taxes have probably had more public relations value than any real impact on highway finance. (*Nova Scotia and New Brunswick both established small trust funds in 1989 when fuel taxes were increased. Alberta Transportation and Utilities, for a few years showed "dedicated tax" revenues in its annual report. There may have been other highway departments that also did this. However, in all of these cases, there was really no change in the way roads were financed. Highway departments continued to be financed from consolidated tax funds.*)
- Linking Specific Road Taxes with Road Budgets: In some ways a minor development—the amount of money involved is not large—Saskatchewan has found a way of making sure that taxes paid by some vehicles result in money being spent on

roads. Under the "Transportation Partnership Program," carriers that want to operate trucks larger or heavier than normal are allowed to do so under permit. The fee for this is calculated on the basis of the benefit received by the carrier (bigger payloads mean lower unit costs) minus any increase in infrastructure costs. Fee revenues are placed in a special fund—not the consolidated tax fund—and the money is used for road improvements. A minor development, but an important one as this is one of the few instances in Canada where the payment of a specific road tax is directly tied to road spending.

- Road Financing Agencies: Finally, British Columbia established the BC Transportation Financing Authority in 1993 as a crown corporation with broad responsibilities to finance transportation infrastructure. The BCTFA uses its known stream of fuel tax revenues—2¢ per litre from all gasoline and diesel sold in the province plus a tax of $1.50 per day on vehicle rentals—to borrow money and finance new road and related infrastructure. It also finds partners—private sector, local governments—to help finance specific projects.

These changes, some more successful than others, have had the effect of putting the supply and operation of roads in Canada on a more commercial footing. However, none of these initiatives has been aimed directly at internalizing social costs. They have primarily been aimed at reducing the costs to design, operate and maintain roads and to raise the funds necessary for the construction and maintenance of new facilities.

6 OBSERVATIONS AND CONCLUSIONS

6.1 Conclusions

Conceptual Issues in Social Cost Internalization

Transportation activity imposes external impacts on present and future generations. These include air pollution, noise pollution, climate change, accident/crash damages, congestion costs and unallocated wear and tear of infrastructure. There appears to be general agreement on the theoretical merits of internalizing transportation externalities. That there would be efficiency gains from transportation pricing based on full social cost is generally well accepted. There is, however, much less agreement on the magnitude and extent of transportation externalities and on the means of including externalities in practical decision-making. There are also a host of concerns over the potential impacts of any moves towards further internalization, especially the public acceptance of higher taxes on travel and transportation, and possible limitations on transportation that might accompany internalization

Social Cost Quantification

The full quantification of the costs of externalities requires a number of steps, each of which involves difficult quantification issues. Externalities require the formulation of relationships between:

- the magnitude of the external by-products and the level of the source activity/output,
- the presence of the by-products and their effects on people, plants and animals, and
- the value society places on these effects/consequences.

The literature dealing with the external costs of transportation activity demonstrate a wide range in the estimated magnitude of the externalities, and to a lesser extent, a range in the type of individual cost items that should be included in any quantification of externalities. Within the confines of a single study, the estimated costs of individual component effects can range by more than a factor of ten. When examined across a number of sources, the range of estimated costs is expanded by additional orders of magnitude. This is a consequence of uncertainty in the establishment of causal relationships. In addition, agreement on input parameters requiring assumptions is lacking, as are base data in many cases.

There is general agreement that the social cost of road transport accidents is high. However, there is little agreement on how much should be considered an externality. The range of external cost estimates varies from it being considered the largest road transport externality by some European and U.S. studies to it being considered almost fully captured by insurance charges by the RCNPT. We note that none of the studies we assessed had separated the role of alcohol in road crashes. We believe that a full social cost evaluation should include the role of all causal factors and any evaluation that Transport Canada undertakes in allocating the external costs of motor vehicle crashes should include an assessment of the role and revenue contribution of alcohol.

The dominant sensitivities are in the costs attributed to health effects and congestion effects. The underlying estimates of the value of life and value of time are critical. Ongoing research, particularly into the health linkages to PM, may well narrow the range of estimates but it will remain substantial.

The external impacts of travel and transportation are highest in urban areas, to the extent that the largest impact components (congestion and health effects of emissions) are highly population dependent. Climate change is the one identified external impact of transportation activity that is apparently independent of location and time.

The Means of Internalizing Social Costs

Our focus is on market measures, however, we do not dismiss the importance of the other measures. Non-market measures such as information / moral persuasion, regulatory measures and infrastructure provision play an important role.

Market measures include facility use fees, fuel/carbon taxes, fee differentiation and marketable permits. With respect to market-based internalization measures, it is unlikely that any one measure will provide the proper impetus for all modes, or even all situations within a single mode. Coordination of a wide range of measures will be required to achieve a reasonable alignment of the price of transportation as perceived by users with the total social costs. Fuel consumption-based taxes are the easiest means of affecting all modes, but would not address external costs such as congestion and would not adequately distinguish between locations where the associated emission from fuel consumption has serious consequences and those locations where the impact is slight.

Tradable permits in the transportation context appear to be somewhat more appropriate for addressing climate change initiatives than for addressing other externalities and in that application would be more efficiently directed at large organizations such as railroads, airlines, and major long-distance trucking companies. Upstream applications of tradable permits for CO_2 might also overcome the inefficiencies of dealing with end-use transportation (and residential/commercial heating) emitters.

Experience with Social Cost Internalization

For the most part, the theoretical and practical literature, as well as existing initiatives, has been focused on road transportation. There is agreement in the literature that a combination of measures will be necessary. Electronic toll collection systems are the most effective available measure to meet the time/location dependent sensitivity of congestion and environmental effects, and would appear to be the best choice for high-density urban areas. Other forms of road-usage fees (fuel taxes, differentiated registration fees) would be more cost effective in intercity and lower density urban areas. In terms of timing, a differentiated schedule of registration fees in combination with increased fuel taxation is a possible interim step towards a long-term objective of urban road pricing and distance-based fees for trucks.

With respect to initiatives taken to internalize transportation's external costs, we note that while there has been much attention directed at social cost determination and allocation in the past decade, with the exception of a few isolated cases, little action has been taken. While there is a significant worldwide trend in the use of electronic road pricing technology, there is little evidence of efficient social cost allocation in its applications. Where action has been taken it has been strongly tied to revenue objectives or to very specific environmental or related concerns. The exceptions are Singapore's very stringent suite of actions directed at road use and the evolution in replacing income/ general taxes with fuel taxes by many Europe countries.

Europe has also been the principal location of differentiated fees for trucks. Sweden's lead in allocating differentiated fees in the air and marine sectors could be reviewed as candidate models for Canada's air and marine sectors. Outside of some European airport landing fees, we detected little attention being given to the social cost components of noise, and little attention anywhere to land use.

Tradable permits have been shown to play an important role in providing flexibility and efficiency to command and control type regulations when applied to large central facilities with broad side effects. One of the more successful North American applications of trading in the upstream supply side of transportation was limited to a phase-in period of more stringent emission regulation.

6.2 Observations on Salient Issues for Canada

It is clear that equity and political acceptance issues will accompany any movement towards efficient social cost allocation. In this respect we offer the following observations.

6.2.1 Marginal Versus Average Total Cost

The economics literature and accepted theory dictate that optimal pricing should be based on a floor of *marginal cost* (in the case at hand*, marginal social cost*). For cost recovery—more the domain of accountants than of theoretical economists—pricing is normally considered in *average total cost* terms. Total social cost estimates developed on a system average or regional average cost basis with allocation among the various classes of traffic should be feasible. Data considerations would probably preclude marginal or incremental treatment. In this respect, we note that, as the time horizon of an analysis increases (to a limit), the very *long run variable* or *marginal cost* should be expected to approach *average total cost*. Yet, this only partially closes the gap as economists usually focus on short run variable cost.

For truly efficient social cost internalization pricing, each individual carrier, shipper, traveller or user should be faced with the *marginal social costs* of her/his/its activities. There are administrative practicality and public acceptability limits to this. Although also somewhat problematical on both of these counts, aggregate social cost recovery might be more readily implemented in the intermediate term, say some three to ten years.

From our perspective, administrative practicality and public acceptability must be considered here. It would seem feasible (although not easy) to develop social cost estimates on a system average total cost vehicle-kilometre or tonne-kilometre basis (as were prepared by the Royal Commission on National Passenger Transportation). Data might or might not allow us to estimate the marginal social cost of a single vehicle over a specific route at a specific time of day and day of the year. Development of such estimates for each vehicle over each route at each time etc. would obviously be impractical and pricing on such an individual basis would seem even less realistic. Marginal, incremental and decremental analyses should prove more feasible for a route specific example or perhaps on a sample basis. The social cost consequences of road pricing regimes that caused certain traffic shifts could be estimated (this presumes knowledge of the *elasticities* involved), as could the consequences of various infrastructure investments.

The above said, it would be worrisome to totally abandon the theoretically correct approach without thoroughly understanding the potential efficiency consequences of doing so. This is an issue that remains to be resolved. The ECMT's guiding principle of linking charges as closely as possible with the underlying social costs incurred is applicable to Canada. The combination of measures noted in the first paragraph of the *Experience* sub-heading above addresses this principle. Nonetheless, some degree of approximation of the time-and-location-dependent marginal social cost will have to suffice. In some applications, the average total cost figures generated by the accounting system might suffice.

6.2.2 Practicality and the Assignment of Dollar Figures to Externalities

The substantial uncertainty notwithstanding, it should be possible to develop reasonable measures of the magnitude of the total social cost of travel and transport under varying Canadian circumstances. Of course, preparation of a credible set of computations for all modes under a range of operational circumstances and for various regions of the country would be a substantial task. The research program developed by Lake et al. in the *Road Pricing* study—although broader than social cost estimation—amounted to more than $ 2 million and would require in excess of two years. An understanding of the nature and behaviour of various social costs would have to be achieved. There are also important regional differences on which analyses might focus; for example, the effects of emissions on health are a particular concern in Southern Ontario and the B.C. Lower Mainland.

The thoroughness of the preliminary research notwithstanding, for charges based on externalities costing, the governments concerned will have to decide how much they are prepared to compromise among the regulatory cost determination principles of objective determination, testability (auditability and demonstrability), causality, specificity, and process efficiency.

There are other dimensions of practicality that are at least as important as social cost estimation—political feasibility and administrative practicality. A political climate where Canadian governments were prepared to institute environmental and safety externality charges would have to be cultivated. Then there are questions of the levels of government that should have authority to impose charges with respect to the various categories of externalities, and to receive the revenues from them. There are also questions of intersectoral, interprovincial and international (especially Canada-U.S.) externality charges consistency and harmonization.

6.2.3 Equivalent Treatment of Modes

So far as formal policy statements are concerned, the Canadian federal and many other governments espouse the equal treatment of modes. Yet, reality is often quite different, and the *status quo* is the product of a long history. The fact is widely recognized and decried that most roads are built on public lands for which no user charges are levied, while railways own their own infrastructure and pay real estate property taxes on it (sometimes at double the regular level), with ports and airports often falling between the two. Current federal and provincial transportation fuel taxes certainly do not feature modal equality, and the intersectoral situation is much worse.[51] Intratransport efforts at reversing such inequality have met some success, especially for the larger airports, and there has even been progress in the areas of rail fuel and property taxes. Nonetheless, much of the modal inequality issue remains the captive of its history and sudden disruption of this situation would cause substantial adjustment.

From another perspective, it is necessary to distinguish between a pricing regime that would apply user fees that reflect full social, economic and environmental costs, and targeted *ad hoc* environmentally-motivated financial penalties to deter use of a specific transportation mode that is deemed to be socially and environmentally undesirable. Although use-deterrence would be among the consequences of a pricing regime to rendering transportation sustainable from an economic, social, financial and environmental viewpoint, modally targeted pricing violates the principal of modal equality (even if designed to counter intermodal inequalities).

6.2.4 Recycling of Revenue

The introduction of any significant level of new environmentally related taxes or other charges made by government for transportation need to be handled so as to achieve *revenue neutrality* through appropriate *revenue recycling.*[52] The OECD and others have noted that *revenue neutrality* is critical to public acceptance of the internalization of environmental and other costs related to transportation. There is no reason to think that the situation would be any different in Canada. Without suggesting which Canadian taxes might be altered, we note that many EU member countries have (or are proposing to) reduced personal income taxes and social security levies as the means of recycling revenues.

We note that suggestions of new charges on transportation (or any other sector) seem to elicit a reaction that Canada's competitiveness will be compromised. Of course, this may be false; however, a degree of concern is legitimate—particularly as respects regional advantages. From a national perspective, Canada's competitiveness could be affected if its environmental charges are significantly higher than those of its main trading partners

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51 With only trivial exceptions, there are no special charges levied on petroleum fuel consumed by sectors other than transportation.

52 It is not clear if this requirement applies to new tolls introduced solely as a means of financing provision of new transportation infrastructure.

are but the net effect need not necessarily be negative. We also cannot lose sight of the fact that, even with revenue recycling, there will inevitably be winners and losers with any change in how externalities are treated. It may well be that the losers will be those who consume a significant amount of transportation, yet to provide targeted compensation for higher transportation expenditures may well defeat the whole purpose of the internalization process.

6.2.5 Horizontal Versus Vertical Equity Concerns

In Canada, the poorer segment of society includes many rural residents and those who live in relatively remote areas. On average, these persons operate older relatively polluting vehicles and must use automobile travel more than do the more affluent residents of major metropolitan areas. As we noted in Chapter 5, urban areas experience the highest social costs of transportation (both from pollution and congestion). Road pricing schemes can best address the different level of externalities experienced in urban areas while energy taxes or carbon taxes can address the more global influence of climate change and acid rain.

Full social cost recovery pricing, or any other policy, is only feasible if it can achieve acceptance within the national, provincial and local political structures that would have to shoulder responsibility for it. While there is some vocal support for policies whereby those who pollute and congest the infrastructure would be required to pay for the environmental and health damage and the delay and inconvenience caused, emission based fees or other charges with regressive characteristics would not be popular. Implementation would be expected to cause situations where those who can afford to pay continue to pollute and congest and those who can not afford the price use alternative modes or do not travel or ship.

There are no easy answers to such problems; however, we agree with the position taken by the ECMT and the RCNPT that issues of vertical equity are best dealt with through the general taxation base, rather than by distorting pricing mechanisms in order to seek efficient allocation of resources.

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Report 1: *The Annualized Social Cost of Motor-Vehicle Use in the U.S., 1990-1991: Summary of Theory, Methods, Data, and Results* (M. Delucchi)

Report 2: *Some Conceptual and Methodological Issues in the Analysis of the Social Cost of Motor-Vehicle Use* (M. Delucchi)

Report 3: *Review of Some of the Literature on the Social Cost of Motor-Vehicle Use* (J. Murphy and M. Delucchi)

Report 4: *Personal Nonmonetary Costs of Motor-Vehicle Use* (M. Delucchi)

Report 5: *Motor-Vehicle Goods and Services Priced in the Private Sector* (M. Delucchi)

Report 6: *Motor-Vehicle Goods and Services Bundled in the Private Sector* (M. Delucchi, with J. Murphy)

Report 7: *Motor-Vehicle Infrastructure and Services Provided by the Public Sector* (M. Delucchi, with J. Murphy)

Report 8: *Monetary Externalities of Motor-Vehicle Use* (M. Delucchi)

Report 9: *Summary of the Nonmonetary Externalities of Motor-Vehicle Use* (M. Delucchi)

Report 10: *The Allocation of the Social Costs of Motor-Vehicle Use to Six Classes of Motor Vehicles* (M. Delucchi)

Report 11: *The Cost of the Health Effects of Air Pollution from Motor Vehicles* (D. McCubbin and M. Delucchi)

Report 12: *The Cost of Crop Losses Caused by Ozone Air Pollution from Motor Vehicles* (M. Delucchi, J. Murphy, J. Kim, and D. McCubbin)

Report 13: *The Cost of Reduced Visibility Due to Particulate Air Pollution from Motor Vehicles* (M. Delucchi, J. Murphy, D. McCubbin, and J. Kim)

Report 14: *The External Damage Cost of Direct Noise from Motor Vehicles* (M. Delucchi and S. Hsu) (with separate 100-page data Appendix)

Report 15: *U.S. Military Expenditures to Protect the Use of Persian-Gulf Oil for Motor Vehicles* (M. Delucchi and J. Murphy)

Report 16: *The Contribution of Motor Vehicles and Other Sources to Ambient Air Pollution* (M. Delucchi and D. McCubbin)

Report 17: *Tax and Fee Payments by Motor-Vehicle Users for the Use of Highways, Fuels, and Vehicles* (M. Delucchi)

Report 18: *Tax Expenditures Related to the Production and Consumption of Transportation Fuels* (M. Delucchi and J. Murphy)

Report 19: *The Cost of Motor-Vehicle Accidents* (M. Delucchi)

Report 20: *Some Comments on the Benefits of Motor-Vehicle Use* (M. Delucchi)

Report 21: *References and Bibliography* (M. Delucchi)

Appendix A

Abbreviations

BTS = Bureau of Transportation Statistics (U. S. Department of Transportation)

CO = carbon monoxide

CO_2 = carbon dioxide

dB = decibel

DOE = Department of Energy

DOT = Department of Transportation

EPA = United States Environmental Protection Agency

GDP = Gross Domestic Product

HC = hydrocarbon

HDDT = heavy-duty diesel truck

HDDV = heavy-duty diesel vehicle

HDGT = heavy-duty gasoline truck

HDGV = heavy-duty gasoline vehicle

HDT = heavy-duty truck

HDV = heavy-duty vehicle

HGV = heavy-goods vehicle

IEA = International Energy Agency

LDDT = light-duty diesel truck

LDDV = light-duty diesel vehicle

LDGT = light-duty gasoline truck

LDGV = light-duty gasoline vehicle

LDT = light-duty truck

LDV = light-duty vehicle

MC = marginal cost

MOBILE5 = EPA's mobile-source emission-factor model.

MSC = marginal social cost

NO_x = nitrogen oxides

OECD = Organization for Economic Cooperation and Development

O_3 = ozone

PART5 = EPA's mobile-source particulate emission-factor model

PM = particulate matter

PM_{10} = particulate matter of 10 micrometers or less aerodynamic diameter

$PM_{2.5}$ = particulate matter of 2.5 micrometers or less aerodynamic diameter

PKM = passenger kilometres of travel

PMT = passenger-miles of travel

SO_x = sulfur oxides

USDOE = U. S. Department of Energy

USDOT = U. S. Department of Transportation

VKM = vehicle-kilometres of travel

VMT = vehicle-miles of travel

WTA = willingness-to-accept

WTP = willingness-to-pay

Appendix B

Revealed Preference Methodologies Identifed by Levinson et al.

Source: David Levinson, David Gillen, Adib Kanafani, Jean-Michel Mathieu, [1996]

Hedonic Models: The most widely used estimates of the cost of noise are derived from hedonic models. These assume that the price of a good (for instance a home) is composed of a number of factors: square footage, accessibility, lot area, age of home, pollution, noise, etc. Using a regression analysis, the parameters for each of these factors are estimated. From this, the decline in the value of housing with the increase in the amount of noise can be estimated. This has been done widely for estimating the social cost of road noise and airport noise on individual homes. In theory, the value of commercial real estate may be similarly influenced by noise. In our literature review thus far, no study of this sort has been found. Furthermore, although noise impacts public buildings, this method cannot be used as a measure since public buildings are not sold.

Similarly, when determining some of the costs of noise, one could investigate how much individuals might be willing to pay for vehicles which are quieter. Like a home, a hedonic model of vehicle attributes could be estimated. A vehicle is a bundle of attributes (room, acceleration, MPG, smooth ride, quiet, quality of workmanship, accessories) which influence its price, also an attribute.

Unit/Cost Approach: A simple method, the "unit cost (Rate) approach" is used often for allocating costs in transit. This method assigns each cost element, somewhat arbitrarily, to a single output measure or cost center (for instance, Vehicle Miles Travel, Vehicle Hours Travel, Number of Vehicles, Number of Passengers) based on the highest statistical correlation of the cost with output.

Wage/Risk Study: A means for determining the economic cost of risk to life or health or general discomfort is by analyzing wage/salary differentials based on job characteristics, including risk as a factor.

Time Use Study : This approach measures the time used to reduce some risk by a certain amount. For instance, seatbelts reduce the risk of injury or using pedestrian overpass may reduce the risk of being hit by a car. The time saved has a value, which may inform estimates of risk aversion.

Years Lost plus Direct Cost : This method estimates the number of years lost to an accident due to death and years lost from non-fatal injuries. It also the monetary costs of non-life damages. However, it defines life in monetary terms. While it may have some humanistic advantages in that it does not place a dollar value on life, defining life through dollars and sense may have some practical value. Defining life through dollars and sense may help us assess whether an improvement, with a certain construction cost and life-saving potential, is economically worthwhile.

Comprehensive : This accident costing method extends the Years Lost plus Direct Cost method by placing a value on human life. The value is assessed looking at the tradeoffs people make when choosing to conduct an activity a certain risk level versus another activity at a different risk, but different cost/time. Studies are based both on what people actually pay and what are willing to pay, and use a variety of revealed preference techniques. This is the preferred method of the US Federal Highway Administration.

Human Capital : The Human Capital approach is an accounting approach which focuses on the accident victim's productive capacity or potential output, using the discounted present value of future earnings. To this are added costs such as property damage and medical costs. Pain and suffering can added as well. The Human Capital approach can be used for accidents, environmental health, and possibly congestion costs. It is used in the Australian study Social Cost of Road Accidents (1990). However, Miller (1991) and others discount the method because the only effect of injury that counts is the out-of-pocket cost plus lost work and housework. By extension, it places low value on children and perhaps even a negative value on the elderly. While measuring human capital is a necessary input to the costs of accidents, it cannot be the only input.