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*"Efficiency - Equity - Clarity"*

# **Transportation Cost and Benefit Analysis**

## **Techniques, Estimates and Implications**

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18 March 2005

### **Abstract**

This 275-page document is a comprehensive study of transport benefit and costing research, and a guidebook for applying this information in planning applications. It includes detailed analysis of various transport costs and benefits. Using the best available data, it provides monetized estimates of twenty costs for eleven travel modes under three travel conditions. Costs are categorized according to various attributes: whether they are internal or external, fixed or variable, market or nonmarket.

This document is unique in several important ways. It is one of the most comprehensive studies of its kind, including many cost and benefit categories that are often overlooked. It is the only transportation cost study that is regularly updated as new information becomes available. It provides costs values in a format designed to easily calculate the full costs and benefits of transport activities and options. It is designed to help noneconomists understand and apply economic evaluation techniques. It provides extensive references, many available through the Internet, allowing users to obtain more information on specific subjects as needed.

This study indicates that on average about a third of automobile costs are external and about a quarter are internal but fixed. Other modes tend to have different cost profiles. Fuel efficient and alternative fuel vehicles tend to have somewhat lower external costs. Transit tends to have lower total costs under urban-peak conditions. Ridesharing tends to have the lowest marginal costs. Motorcycles tend to have relatively high costs due to crash risk. Nonmotorized modes (walking and cycling) have minimal external costs, but relatively high travel time costs. Policy and pricing reforms are justified on economic efficiency and equity grounds.

### **Notes:**

1. Unless stated otherwise all costs in this guidebook are in 1996 U.S. dollars and measured in U.S. units (mile, foot, U.S. gallons).
2. *Transportation Cost Analyzer* Software is available from the Victoria Transport Policy Institute to apply costs in this guidebook to planning and policy making.
3. This guide is updated regularly. Users should contact the VTPI for possible revisions if working with a version that is more than 12 months old.

## **Introduction**

*This chapter describes the context and scope of this guidebook, the value of measuring transport impacts, defines and discusses the concepts of “transport” and “cost,” and categorizes costs based on various attributes.*

A smart consumer investigates all costs and benefits of each option prior to making a major purchase decision. Before buying a car you want accurate information on its fuel, insurance, maintenance and repair costs. Similarly, before buying a train or airline ticket you want to know about all fees and taxes, and whether tickets can be changed or refunded. You also want information on the reliability, comfort and safety of each option.

Just as consumers need accurate and comprehensive information when making personal travel decisions, communities need accurate and comprehensive information on the full economic, social and environmental impacts (benefits and costs) associated with each option when making transport policy and planning decisions.

Most people have limited knowledge of transport economics. They would say, “I just want to be able to travel conveniently, safely and affordably, without higher taxes, pollution or conflict with other road users.” Notice the *just* in this statement, reflecting the assumption that these aspirations are modest and reasonable. Yet, they are actually expensive, complex and contradictory. For example, an efficient roadway system requires three to five parking spaces per automobile, plus various services such as traffic signals and policing, totaling many hundreds of dollars a year per vehicle in indirect costs. For each dollar a motorist spends on fuel, businesses and local governments spend more than a dollar to provide parking facilities and traffic services. A motorist thinks, “I pay vehicle taxes and fees so I should get parking and traffic services,” little realizing that what they pay in user charges is insufficient to cover the full costs imposed by their driving.

There are often conflicts between transport objectives. For example, some congestion reduction strategies degrade walking conditions or increase pollution emissions. Conversely, some emission reduction strategies increase consumer costs or traffic congestion. Such tradeoffs must be considered in transport planning and policy making.

Some transport impacts have been widely studied and estimates of their magnitude are easily available. For example, standard methods exist to measure vehicle operation and travel time costs, so it is relatively easy to calculate the value to motorists of increasing road capacity and traffic speeds. Other impacts, such as changes in walking conditions or pollution emissions, are more difficult to quantify. If they are considered at all in transport economic studies, such impacts tend to be described as “intangibles,” with the implication that they are less important than “tangible” costs and benefits. The result is decision-making biased in favor of easy-to-measure impacts at the expense of more-difficult-to-measure impacts.

This guidebook is intended to support more comprehensive transport policy and planning analysis by providing benefit and cost information in a format that is convenient and flexible for evaluating a wide range of options.

## Guidebook Scope

This guidebook provides detailed information on transportation economic impacts (benefits and costs). It examines how benefits and costs vary for different transport options and travel conditions. It primarily considers personal land transport, plus some information on freight and air transport. It includes data from North America, Europe, Australia, New Zealand, Japan, and other parts of the world. This document is regularly updated as new information becomes available.

This guide uses the best available data to develop estimates of the full costs and benefits of various forms of transport, including those that are commonly recognized and some that are often overlooked. It provides an analysis framework which includes estimates of twenty cost per vehicle-mile and passenger-mile for eleven passenger travel modes under three travel conditions (urban-peak, urban off-peak and rural). These values can be used to estimate the incremental benefits or costs that result from transport changes, such as faster, safer or more affordable travel options. This analysis framework helps compare and evaluate transportation activities and planning options.

## Twenty Transportation Cost Categories

- |                        |                     |                               |                          |
|------------------------|---------------------|-------------------------------|--------------------------|
| 1. Vehicle Ownership   | 6. External Crash   | 11. Roadway Land Value        | 16. Resource Consumption |
| 2. Vehicle Operation   | 7. Internal Parking | 12. Traffic Services          | 17. Barrier Effect       |
| 3. Operating Subsidies | 8. External Parking | 13. Transport Diversity Value | 18. Land Use Impacts     |
| 4. Travel Time         | 9. Congestion       | 14. Air Pollution             | 19. Water Pollution      |
| 5. Internal Crash      | 10. Road Facilities | 15. Noise                     | 20. Waste Disposal       |

This guidebook includes individual chapters on various transport costs. Each of these chapters includes a description and discussion of the cost, summaries of various studies of its magnitude and monetized (measured in monetary values) value, discussion of its variability and equity impacts, plus references and resources for more information. Each of these chapters provides default values reflecting typical costs for the eleven modes under the three travel conditions, plus detailed information for modifying the default values to reflect specific conditions. Users can use this information to develop more appropriate cost values for a particular mode, used at a particular time, at a particular location.

## Eleven Travel Modes (definitions in Chapter 5.0)

- |                                                                                                   |                                                                          |
|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| 1. Average Automobile.                                                                            | 7. Electric Bus/Trolley.                                                 |
| 2. Compact (Fuel Efficient) Car.                                                                  | 8. Motorcycle.                                                           |
| 3. Electric Car.                                                                                  | 9. Bicycle.                                                              |
| 4. Van or Light Truck.                                                                            | 10. Walk.                                                                |
| 5. Rideshare Passenger (the incremental cost of an additional carpool, vanpool or transit rider). | 11. Telework. (telecommunications that substitutes for physical travel). |
| 6. Diesel Bus.                                                                                    |                                                                          |

## **Why Measure Transportation Impacts?**

Transportation costing and benefit analysis has many specific applications, as summarized below and described in detail in Chapter 3.

### **Improved Vocabulary for Discussing Impacts**

There is often confusion over how various transport impacts are defined and categorized. This guidebook provides definitions and discussions of the nature of each impact, plus reference information of additional information.

### **Policy and Planning Evaluation**

Policy and planning decisions often involve economic analysis to determine whether a particular option is cost-effective, and which option provides the greatest overall benefits. Conventional evaluation practices often exclude some impacts, which can result in solutions to one problem that exacerbate other problems. This guidebook provides a comprehensive economic evaluation framework that can help evaluate the full costs of a particular transport activity or project, and compare the incremental benefits and costs of different options.

### **Optimal Pricing**

A general economic principle is that prices should reflect full marginal costs. Cost analysis is important to help identify fair and efficient pricing, including fuel taxes, road and parking fees, insurance pricing, vehicle fees and taxes, and road pricing.

### **TDM Evaluation**

Transportation Demand Management (TDM, also called *Mobility Management*) includes various strategies that result in more efficient use of transport resources. TDM evaluation requires more comprehensive analysis than normally used for transport planning because it requires determining the economic impacts of various travel changes, including changes in transport diversity and shifts in travel time, distance, destination and mode. This guidebook provides information on the costs and benefits of different transport modes and conditions to help calculate incremental benefits and costs from various TDM strategies.

### **Equity Evaluation**

There are several types of transportation equity analysis, each of which requires different types of benefit and cost information. This guidebook describes different types of transportation equity, discusses the equity impacts of various transport modes and costs, and provides information on the benefits and costs for use in equity analysis.

### **Economic Development Impacts**

*Economic Development* refers to progress toward a community's economic goals, including increases in economic productivity, employment, business activity and investment. Various techniques can be used to measure the economic development impacts of a particular transport policy or project. This guidebook discusses how such impacts can be evaluated and provides information on economic benefits and costs that can be used for evaluation.

## Defining Transport

How transportation is [measured](#) affects planning and evaluation decisions.<sup>1</sup> Transport is often defined as *mobility*, the movement of people and goods, measured in terms of travel distance and speed. But movement is seldom an end in itself. Even recreational travel usually has a destination. The ultimate goal of most transport is [accessibility](#), the ability to reach desired goods, services, activities, and destinations.<sup>2</sup>

Transport professionals often measure transport system performance based on *vehicle traffic* conditions (e.g. average vehicle speed, roadway Level of Service, congestion delay). This tends to skew planning decisions to favor automobile travel improvements. For example, wider roads, higher traffic speeds and larger parking facilities benefit motorists, but tend to create land use patterns less suited for transit, cycling and walking. If the benefits to motorists are measured, but disbenefits to other modes are not, transport planning decisions will tend to favor automobile travel at the expense of other modes.

Defining transport as *mobility* (measured as person-miles or person-trips) acknowledges that other modes (transit, ridesharing, bicycling and walking) also provide access. But even this definition is limited. Only if transport is evaluated in terms of *access* can strategies that reduce the need for travel, such as telework and more efficient land use, be considered as solutions to transport problems. Increased mobility may simply indicate an overall reduction in access. John Whitelegg states,

“It is the ease of access to other people and facilities that determines the success of a transportation system, rather than the means or speed of transport. It is relatively easy to increase the speed at which people move around, much harder to introduce changes that enable us to spend less time gaining access to the facilities that we need.”<sup>3</sup>

### [Evaluating Accessibility](#)<sup>4</sup>

During a typical week you probably visit many destinations. The time and expense required for these trips indicates your quality of access. This depends on both individual factors such as your physical ability, wealth and whether you can drive; and community factors such as the capacity of roads, quality of transit service, ease of pedestrian travel, and land use patterns.

Some destinations, such as the home of a friend or a special attraction, are unique. The only way to improve access to them is to improve mobility. Other destinations are more flexible. You usually choose a store or bank branch that is nearby. Access to these destinations can be improved if your mobility improves, if their proximity increases, if they are grouped more efficiently (so you can perform more errands at once), or if alternative forms of access (such as a new communication or a delivery service) reduce your need to visit destinations physically.

<sup>1</sup> VTPI, “Measuring Transportation,” *Online TDM Encyclopedia*, Victoria Transport Policy Institute ([www.vtpi.org/tdm/tdm55.htm](http://www.vtpi.org/tdm/tdm55.htm)), 2002.

<sup>2</sup> BTS, *Special Issue on Methodological Issues in Accessibility: Journal of Transportation and Statistics*, Vol. 4, No. 2/3, Bureau of Transportation Statistics ([www.bts.gov](http://www.bts.gov)), Sept/Dec 2001.

<sup>3</sup> John Whitelegg, “Time Pollution,” *The Ecologist*, Vol. 23, No. 4, July 1993, p. 131.

<sup>4</sup> VTPI, “Accessibility,” *Online TDM Encyclopedia*, Victoria Transport Policy Institute ([www.vtpi.org/tdm/tdm84.htm](http://www.vtpi.org/tdm/tdm84.htm)), 2002.

## Defining “Cost”

What most people call *problems*, economists call *costs*. For example, if somebody says, “Traffic congestion is a terrible problem,” an economist might say, “Traffic congestion is a significant cost.” The term *cost* is more neutral. *Problem* implies something is flawed and must be corrected, while *cost* recognizes that solving a problem involves tradeoffs. Calling congestion a *problem* implies that it must be fixed, but describing it as a *cost* recognizes that a certain amount of congestion may be acceptable compared with the costs involved in eliminating it. Also, *costs* implies that impacts can be quantified. Calling congestion a *problem* indicates nothing about its magnitude but calling congestion a *cost* suggests that it can be measured and compared with other impacts.

*Cost* refers to the trade-offs between uses of resources. This can involve money, time, land, or the loss of an opportunity to enjoy a benefit. Costs and benefits have a mirror-image relationship: a cost can be defined as a reduction in benefits, and a benefit can be defined in terms of reduced costs. For example, time spent traveling is a cost if the same time could be used in other beneficial ways. Lee states,

“The economist’s notion of cost—which is used here—is the value of resources (used for a given input) in their best alternative use. If, for example, less gasoline were used in highway travel, what would consumers be willing to pay for the fuel for some other purpose, or if it were converted instead to heating oil? If less time were used in travel, how valuable would the time be for whatever purpose travelers chose to use it? If clean air were less consumed in dispersing vehicle pollutants, how much would society benefit from using the air to disperse non-highway pollutants or from breathing cleaner air? This concept of costs depends, then, on benefits foregone; there is no separate measure of cost that is distinct from valuation of benefits.”<sup>5</sup>

Costs have various attributes that affect their impacts, which are described below.

### 1. Internal, External and Social

*Internal* (also called *user* or *private*) costs are borne by a good’s consumer. *External* costs are borne by others. *Social* costs are the total costs to society, including both internal and external impacts.

Some costs, such as traffic congestion and crash damages are largely imposed by motorists on other motorists, and so are external to individuals but internal within a group (sector). Whether such costs should be considered internal or external depends on the type of problem being addressed. If the only concern is sector level equity (“*It’s unfair that trucks impose costs on car users.*”), sector level analysis may be appropriate. If the concern is either individual level equity (“*It’s unfair that risky drivers endanger safe drivers.*”), or economic efficiency (“*Underpriced road use leads to congestion and inefficiency.*”) then external costs *must* be defined at the individual level. As Mark Delucchi states,

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<sup>5</sup> Douglass Lee, *Full Cost Pricing of Highways*, Na. Transport Systems Center (Cambridge), 1995, p. 7.



It is generally true that, for society to use resources efficiently, each individual who makes a resource-use decision must count as a cost of that use everything that in fact is an opportunity cost from the standpoint of society. It does not matter whether or not motor-vehicle users as a class pay for a particular cost generated “within” the class; what matters is whether or not each individual decision maker recognizes and pays the relevant social marginal-cost prices. If the responsible individual decision maker does not account for the cost, it does not matter then who actually pays for it, fellow user or non-user; the resource [usually] is misallocated, regardless of who pays. To account for a cost, a consumer must know its magnitude and be required or feel obliged to bear it. Generally, a price accomplishes both of these things: it tells the consumer what he must give up in order to consume the item.<sup>6</sup>

Sector level analysis implies that society is unconcerned with costs individuals impose on others in their group. This is arbitrary because it depends on how groups are defined. Should groups be defined by travel mode, geography, income class, or some combination of these attributes? For example, is traffic noise caused by motorists from another neighborhood an internal or external cost? Are motorcyclists included in the same group as car drivers for evaluating noise costs? Are noise costs internal if imposed on cyclists who live in an automobile owning household? Defining externalities at the sector level makes no more sense than to suggest that stealing is acceptable if committed against somebody who shares a common ethnic, consumer or income status.

#### **External Costs Among Automobile Users**

Every household in Francis’ neighborhood owns a car, but that does not eliminate external costs or mean that each household’s external transport costs offset each other. A household that drives more than average, drives dangerously, or has a particularly polluting car imposes net costs on other households, even though they all own cars.

Francis also owns a bike. Her neighbors benefit when she cycles rather than drives because it reduces congestion, crash risk and pollution. These external impacts are economically inefficient if Francis does not receive an incentive to cycle equal to the benefits her neighbors enjoy when she shifts mode. With such an incentive everybody could be better off because Francis would choose to bicycle whenever her neighbors’ benefits is sufficient to induce a shift.

Whether this incentive is positive (neighbors reward each other for bicycling) or negative (motorists must compensate neighbors for their negative impacts) depends on “property rights.” If driving is a right then the neighbors must reward bicycling. If safety and quiet are rights, then motorists must compensation for these external costs. These property rights are often unclear, so in practice a combination of positive and negative incentives are typically applied to encourage individuals to use modes that impose fewer external costs. Regardless of property rights, driving imposes external costs to the degree that not driving provides an external benefit.

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<sup>6</sup> Mark Delucchi, *Annualized Social Cost of Motor Vehicle Use in the U.S. 1990-1991*, Vol. 1, Institute of Transportation Studies ([www.its.ucdavis.edu](http://www.its.ucdavis.edu)), UCD-ITS-RR-96-3 (1), p. 19.

## 2. Variable or Fixed

*Variable* (also called *marginal*) costs are the incremental costs resulting from an incremental change in consumption, and so reflect costs that can be reduced by reduced consumption, for example, if motorists reduce their annual mileage. *Fixed* costs are not affected by consumption. *Sunk* costs are fixed costs incurred in the past, and so are unavoidable. For example, equipment, buildings and land are fixed cost, but they can be sold and their value partly recovered. Planning and rents are sunk costs, resources spent on them cannot be recovered in the future.

Fuel, travel time and crash risk are variable automobile costs, they increase with vehicle mileage. Depreciation, insurance, and registration fees are considered fixed. The distinction between fixed and variable often depends on perspective. For example, although depreciation is usually considered a fixed cost, a vehicle's operating life and resale value are affected by how much it is driven, so depreciation is partly variable over the long term.

## 3. Market or Non-Market

*Market* costs involve goods that are traded in a competitive market, such as vehicles, land and fuel. *Nonmarket* costs involve goods that are not regularly traded in markets such as clean air, crash risk, and quiet. *Monetary* costs are called *expenditures*.

## 4. Perceived or Actual

There is sometimes a difference between users' *perceived* and *actual* costs. Consumers tend to be most aware of immediate costs such as travel time, stress, parking fees, fuel, and individual transit fares, while costs that are only paid occasionally, such as insurance, depreciation, maintenance, repairs and residential parking, are often underestimated.

## 5. Price

*Price* refers to perceived-internal-variable cost, that is, the incremental costs that a user bears for consuming a good. These are the costs that directly affect consumption decisions. For example, a change in fuel prices, parking fees and transit fares affect consumers' travel decisions. Economic efficiency requires that prices reflect the full costs of producing a good to give accurate *market signals*, as discussed in Chapter 3. Price is often defined narrowly to only include monetary costs, but it can also include nonmarket user impacts such as time and risk, since they also affect consumption decisions. Transport planners call this the *generalized cost* of travel.

## 6. Direct or Indirect

Some impacts are *indirect*, with several steps between an activity and its ultimate outcomes.<sup>7</sup> For example, high levels of motor vehicle travel use tend to cause low-density, urban-fringe development (sprawl) and reduce mobility options for non-drivers, resulting in various economic, social and environmental costs. Although it may be difficult to measure a particular vehicle-mile's contribution to such costs, the cumulative

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<sup>7</sup> Louis Berger & Associates, *Guidance for Estimating the Indirect Effects of Proposed Transportation Projects*, Report 403, Transportation Research Board ([www.trb.org](http://www.trb.org)), 1998.



impacts are significant and so should not be ignored. This is similar to the effects of tobacco and alcohol: a single cigarette or drink may do little harm, but is no question that smoking and excessive drinking impose significant costs on society that justify public anti-smoking and responsible drinking campaigns to discourage excessive use. Quantifying indirect impacts requires an understanding of the various steps connecting an activity with its ultimate effects. Whether an activity imposes an indirect cost can be determined using a “*with and without*” test: the difference in impacts with and without a project or policy are considered a result of that project or policy.<sup>8</sup>

If indirect cost values are likely to be criticized in a particular planning process, it may be best to incorporate them qualitatively rather than quantitatively. For example, rather than assigning a dollar value to land use and transport diversity impacts, a study can simply note whether a particular option supports or contradicts a community’s strategic objectives to reduce sprawl and improve travel options for non-drivers.

## **7. Economic Transfers, Resource Costs and Taxes**

*Economic transfers* involve costs or benefits shifts that do not change the total amount of resources available. Pricing and taxes are economic transfers, they are a cost to one group and a benefit (revenue) to another, although any additional administrative or time costs needed to pay the fees are true resource costs. Economic transfers can involve nonmarket costs. For example, driving a larger vehicle tends to increase safety for its occupants but increases risk to other road user, resulting in a transfer of risk. When evaluating such impacts it is important to account for both the benefit and the costs of economic transfers.

Taxes require special consideration in cost analysis. Taxes are usually considered an economic transfer from consumers to governments, and excluded when calculating costs and benefits.<sup>9</sup> Special charges, such as fuel taxes and vehicle registration fees can be considered user fees that internalize external costs, but general taxes, such as standard sales taxes on vehicles, are not, since consumers pay such taxes on other goods.<sup>10</sup> For example, if automobile travel impose external costs of 10¢ per mile, a policy that adds one million vehicle-miles of travel would impose \$100,000 in additional external costs. However, if motorists pay an average of 3¢ per mile in special fuel taxes, the additional driving would cause an additional \$30,000 in fuel tax revenue, so the net external cost is \$70,000. Similarly, a mobility management program that reduces a million vehicle-miles of travel provides \$100,000 in cost savings, minus \$30,000 in reduced fuel tax revenue, resulting in a net gain of \$70,000. General taxes are not considered to offset costs because motorists who drive less are assumed to spend their fuel cost savings on other taxed goods (rents, clothing entertainment), so general tax revenue would not change.

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<sup>8</sup> C. van Kooten, *Land Resource Economics and Sustainable Dev.*, UBC Press (Vancouver), 1993, p. 86.

<sup>9</sup> Ian Heggie and Simon Thomas, “Economic Considerations,” *Transportation and Traffic Engineering Handbook*, Institute of Transportation Engineers/Prentice Hall (Englewood Cliffs, NJ), 1982, p. 426.

<sup>10</sup> FHWA, *1997 Federal Highway Cost Allocation Study Final Report (and Addendum)*, Federal Highway Administration, ([www.fhwa.dot.gov/policy/hcas/summary/index.htm](http://www.fhwa.dot.gov/policy/hcas/summary/index.htm)), 1997 and 2000.

If special taxes are charged instead of, rather than in addition to, general taxes, then only the level of tax above the general tax rate can be considered a user fee. For example, if a jurisdiction charges a 6% general tax, but charges only a 20¢ per gallon special tax on fuel, and gasoline costs an average of \$1.50 per gallon, then the first 9¢ of the fuel tax can be considered the general equivalent, and only the remaining 11¢ per gallon would be considered a user fee, that is, special additional tax revenue charged motorists to pay costs resulting from motor vehicle use.

If one activity is exempted from a broad-based tax, it can be treated as an expenditure. Lee states, “Referring to these as ‘expenditures’ derives from the idea that the result would be the same if all taxpayers paid the tax, and the revenues were then paid out to the favored subset.”<sup>11</sup> Examples of this include the exemption of roadway rights-of-way from property taxes (Chapter 5.6), general sales taxes exemptions on motor vehicle fuel and special petroleum industry tax deductions (Chapter 5.12). Careful analysis is required to determine how tax rates compare with other comparable goods.

## Summary

Table 1-1 shows how motor vehicle costs can be categorized. These distinctions determine how a cost affects decisions. Automobile owners decide how much to drive based primarily on perceived, internal, variable costs. Public agencies tend to be influenced by costs perceived by their constituents, however defined. Current transport planning and investment decisions tend to focus on direct market costs. Indirect and nonmarket costs tend to be undervalued because they are more difficult to measure.

**Table 1-1 Motor Vehicle Cost Distribution (*Italics = Non-market*)**

	Variable	Fixed
<b>Internal (User)</b>	Fuel	Vehicle purchase
	Short term parking	Vehicle registration
	Vehicle maintenance (part)	Insurance payments
	<i>User time &amp; stress</i>	Long-term parking facilities
	<i>User crash risk</i>	Vehicle maintenance (part)
<b>External</b>	Road maintenance	Road construction
	Traffic services	Subsidized parking
	Insurance disbursements	Traffic planning
	<i>Congestion delays</i>	Street lighting
	<i>Environmental impacts</i>	<i>Land use impacts</i>
	<i>Uncompensated crash risk</i>	<i>Social inequity</i>

*How a cost affects transport decisions tends to vary depending on whether it is internal, external, fixed, variable, market, or non-market.*

<sup>11</sup> Douglass Lee, *Full Cost Pricing of Highways*, Na. Transport Systems Center (Cambridge), 1995, p. 31.

### Costs—A Pet Example

A pet dog can often be obtained for a low *price* or for free (*unpriced*). But pet owners quickly discover that dogs impose many *costs*. Some, such as pet food purchased at the store, are *market costs*. Others, such as the nuisance of cleaning up after the animal, are *non-market costs*. Non-market costs can often be estimated using a market cost as a reference, such as the price to hire somebody else to clean up after the dog. Some pet costs, such as registration fees and vet fees, are *fixed*, the price is the same for any size dog, while others such as food, are *variable* because they depend on the animal's size. Some costs, such as a flea infestation, are *indirect*, since it may be difficult to know whether a particular pet introduced a particular flea. Some costs are not separate expenses; they are price *premiums* or extra costs to other expenditures, such as more frequent rug cleaning, or additional housing cost for a larger yard. In addition to the *internal* costs borne by their owners, dogs can impose *external* costs on other people, including noise, smells, messes, and fear. Some of these costs, such as animal control programs, are *government expenditures*. Payments for dog licenses are economic transfers, a cost to pet owners and revenue to government coffers, minus any *transaction* costs involved in collecting such fees. Although owners are concerned mainly with their internal costs, public policies, such as pet licensing and leash laws, must reflect the full social costs of dog ownership.

### Discount Rate in Cost Analysis

When an economic impact occurs can affect how its economic value. In general, future impacts are discounted. Discount rates reflect the *time value of money*, which recognizes that wealth can be invested to generate future profits (increased benefits), so current resources have greater value than future resources, even after adjusting for inflation. *Nominal* discount rates include inflation, while those that are net of inflation are called *real* discount rates. Selecting the correct discount rate is particularly important when evaluating impacts that occur many years in the future, such as the benefits of a highway improvement after 20 years. The higher the rate, the more weight is given to present over future benefits. Capital investment discount rates are typically 6-10%. These rates reflect the return capital could earn in typical alternative investments.

A debate exists as to the discount rate to use for human health and environmental costs imposed on future generations. Conventional discounting implies that costs many years in the future are of little concern now.<sup>12</sup> For example, at an 8% discount rate, costs and benefits occurring 20 years in the future (a typical planning horizon) are worth less than a tenth of their current value. Some analysts argue that these financial assumptions are inappropriate for evaluating human health risk and irreversible environmental impacts.<sup>13</sup> They recommend using a lower discount rate for human health and irreversible environmental costs to give fair consideration to future generations' interests.<sup>14</sup>

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<sup>12</sup> One justification for discounting costs imposed on future generations is the assumption that they will be wealthier, on average, than current generations. Some ecological economists argue that this cannot be assumed, due to resource depletion and environmental degradation.

<sup>13</sup> John Gowdy and Sabine O'Hara, *Economic Theory for Environmentalists*, St. Lucie Press (Delray Beach, Florida), 1995.

<sup>14</sup> Robert Costanza and Herman Daly, "Natural Capital," *Conservation Biology*, Vol. 6, No. 1, Mar. 1992.

## Variability and Uncertainty

Any cost or benefit estimate incorporates some degree of variability and uncertainty. Consider, for example, the valuation of a common commodity such as an apple. At first, it may seem easy to estimate apple costs since they are sold almost everywhere. But their cost varies depending on which apple, and when, where and how it is bought. If purchased in bulk directly from a farmer an apple might cost just a few cents, but if purchased individually at a convenience store, the same apple may cost more than a dollar. Apples are cheaper if purchased wholesale, in bulk or during a special sale, and more expensive if they are imported, out-of-season, organic, or specialty varieties. Estimates of apple costs can vary significantly depending on how they are defined and measured.

Similarly with transport costs and benefits. The values in this report are generic. Of course, actual costs vary depending on factors such as location, time, vehicle condition, etc. For example, average air pollution costs may not apply to a particular situation because vehicle or exposure conditions are not average. Ideally, each cost value should be adjusted to reflect each specific applications. For example, when calculating parking cost savings from reduced automobile trips in a particular area, an analyst might first use the generic numbers from this report, adjust them based on local conditions (such as land values), and if even greater precision is needed, perform a detailed study of local parking costs, in which case some references in this report may be useful guides.

Because transport cost analysis involves new areas of research, limited data sources, and complex modeling, estimates incorporate various levels of uncertainty. This is not a unique problem; individuals, businesses, and society often face uncertainty when assessing costs and benefits. For example, a business must invest in a new factory without knowing exactly what the project will cost or the future prices they will get from the factory's products. As stated by one expert in non-market costing, "*A crude approximation, made as exact as possible and changed over time to reflect new information, would be preferable to the manifestly unjust approximation caused by ignoring these costs, and thus valuing environmental damage as zero.*"<sup>15</sup>

Some economic analyses only include costs that are commonly accepted and easily quantified. Excluding or using low estimates of relatively uncertain costs is often defended as being "conservative," implying that this approach is cautious. Use of the word *conservative* in this context is confusing because it often results in the opposite of what is implied. Low *cost* estimates undervalue damages and risks, which is less cautious and conservative than would be higher cost estimates. In practice, low estimates of indirect and non-market costs can lead to increased social and environmental damages. For example, low estimates of pollution costs reduce the justification for control measures, resulting in more emissions.

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<sup>15</sup> Richard Ottinger, "Incorporating Externalities - The Wave of the Future," in *Expert Workshop on Lifecycle Analysis of Energy Systems*, OECD (Paris; [www.oecd.org](http://www.oecd.org)), 1993, p. 54.

The *precautionary principle* applies a high standard of protection to damages that are potentially catastrophic.<sup>16</sup> *Option value* refers to the benefits of maintaining choices and avoiding irreversible losses.<sup>17</sup> Examples of irreversible impacts include species extinction and climate change. Many land use impacts, such as draining wetlands may be irreversible within human lifetimes, although not totally irreversible.

Another way to deal with uncertainty is to use cost ranges rather than point estimates. This makes it possible to perform sensitivity analysis by test how higher and lower values affect results. For example, an analyst might see whether a mobility management program is still justified if relatively low parking and congestion cost estimates are used. Minimum and maximum estimates of automobile costs are provided in this report to facilitate this sort of analysis.

Some cost estimates with a relatively high degree of uncertainty are included in this report, provided that the existence of the cost can be demonstrated, there is compelling evidence that the cost is significant in magnitude, and the resulting estimate is within the expected range relative to other costs. Assuming that the variation among the uncertainty is random, the over- and under-estimates among these estimates will tend to cancel out. Including such estimates is more accurate and more conservative than setting their value at zero, which consistently underestimates total costs.

It may be unnecessary to use all of the cost estimates in this report in a particular application. Some costs are controversial and may invoke disputes that cannot be resolved in a transport planning process. For example, some people refuse to recognize costs associated with climate-changing air emissions or low-density, urban-fringe development patterns. Other costs may be so small in a particular situation that they can be considered insignificant. Users should apply those that make sense in their political and geographic circumstances. However, if cost categories are excluded from quantitative analysis they can often be described qualitatively.

For example, when evaluating various transportation improvements in a community you might choose to not quantify land use and transport diversity impacts, on the grounds that they are indirect and difficult to measure, but still describe how increased urban roadway capacity is likely to stimulate low-density, urban-fringe, automobile-dependent development patterns, while other types of transport improvements usually results in more infill and clustered land use, and can increase travel options for non-drivers. This discussion could include information from the *Land Use Impacts* and *Transportation Diversity* chapters of this report concerning the economic, social and environmental value of these impacts, even if they are not quantified in monetary units.

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<sup>16</sup> Andrew Jordan and Timothy O’Riordan, *The Precautionary Principle In UK Environmental Law and Policy*, Center for Social and Economic Research on the Global Environment (London), 1994.

<sup>17</sup> Hanley and Spash, *Cost-Benefit Analysis and the Environment*, Elgar (Brookfield), 1993, p. 153.

### **Uncertainty in Decision Making: Illustrative Example**

Accurate analysis requires that best available cost estimates be used, rather than treating uncertain costs as having zero value. This is *conservative* because it reduces the tendency to overestimate benefits and understate total costs. The following story illustrates this point.

Lead is an insidious neurotoxin. It is especially harmful to children, causing mental retardation and stunted growth. It is cumulative. Small exposures from different sources can build up over months or years. Without sophisticated chemical tests it is difficult to detect. Lead was widely used in plumbing and cooking utensils during the Roman Empire, and some historians suspect that the resulting poisoning contributed to the empire's decline. Imagine a Roman doctor approaching Emperor Augustus in 26 B.C.:

*“Emperor, I warn you that lead water pipes and cooking pots may cause sickness among our people. Leading scientists believe that they should not be used.”*

The Emperor replies, *“Do you have proof of this claim, citizen?”*

*“Families who use lead plumbing and cooking pots appear to have more sickness and the children learn slower than in families that use other materials.”*

The Emperor consults with advisors and replies, *“Do not be so critical. Lead plumbing is an important innovation of our Empire. Our engineers are proud of their water systems. How could they be bad? Only lead cooking pots produce the sweet fractum [stewed fruit] that we love. Nobody should imply that families who enjoy these products, our entire ruling class, are stupid. That would damage the Empire's reputation. Substitutes to lead are expensive and difficult to use. We will not change unless you provide absolute proof that lead is harmful.”*

Thus, a failure to use precaution when evaluating long-term impacts could have caused the collapse of one of the world's greatest and most technically advanced empires.



## Information Resources

*Information on general transportation evaluation issues are described below.*

Ian Bateman, Brett Day, Iain Lake and Andrew Lovett, *The Effect of Road Traffic on Residential Property Values: A Literature Review and Hedonic Pricing Study*, Scottish Executive Development Department ([www.scotland.gov.uk/library3/housing/ertpv.pdf](http://www.scotland.gov.uk/library3/housing/ertpv.pdf)), January 2001.

DETR, *Guidance on the Methodology for Multi-Modal Studies*, DETR ([www.dtlr.gov.uk/itwp/mms](http://www.dtlr.gov.uk/itwp/mms)), 2000.

EEA, *Indicators Tracking Transport and Environment Integration in the European Union*, European Environment Agency, European Union (<http://org.eea.eu.int/PR>), 2001.

FHWA, *Environmental Guidebook*, Federal Highway Administration (<http://environment.fhwa.dot.gov/guidebook/index.htm>), 2004. Provides policies, procedures, and guidance related to the environment and transportation.

José A. Gómez-Ibáñez, William B. Tye and Clifford Winston (editors), *Essays in Transportation Economics and Policy: A Handbook in Honor of John R. Meyer*, Brooking Institution ([www.brookings.edu](http://www.brookings.edu)), 1999, available at (<http://brookings.nap.edu/books/0815731817/html>).

Per Kågeson, *Getting the Prices Right: A European Scheme for Making Transport Pay Its True Costs*, European Federation for Transport and Environment ([www.t-e.eu](http://www.t-e.eu)), 1994.

Richard C. Porter, *Economics at the Wheel; The Costs of Cars and Drivers*, Academic Press ([www.hbuk.co.uk/ap](http://www.hbuk.co.uk/ap)), 1999.

European Transport Pricing Initiatives ([www.transport-pricing.net](http://www.transport-pricing.net)) includes various efforts to develop more fair and efficient pricing.

Environmental Valuation Reference Inventory ([www.evri.ca](http://www.evri.ca)) is a searchable storehouse of empirical studies on the economic value of environmental benefits and human health effects. It is sponsored by a number of major North American and European organizations.

FHWA, *Transportation Performance Measures Toolbox*, Federal Highway Administration ([www.ops.fhwa.dot.gov/travel/deployment\\_task\\_force/perf\\_measures.htm](http://www.ops.fhwa.dot.gov/travel/deployment_task_force/perf_measures.htm)), 2000.

FDOT, *Quality/Level of Service Handbook*, Florida Department of Transportation ([www11.myflorida.com/planning/systems/sm/los/los\\_sw2.htm](http://www11.myflorida.com/planning/systems/sm/los/los_sw2.htm)), Feb. 2002.

David J. Forkenbrock and Glen E. Weisbrod, *Guidebook for Assessing the Social and Economic Effects of Transportation Projects*, NCHRP Report 456, TRB ([www.trb.org](http://www.trb.org)), 2001.

Dr. Paul M. Johnson, *A Glossary of Political Economy Terms*, ([www.auburn.edu/~johnspm/gloss/index.html?http://www.auburn.edu/~johnspm/gloss](http://www.auburn.edu/~johnspm/gloss/index.html?http://www.auburn.edu/~johnspm/gloss)), Dept. of Political Science, Auburn University.

Douglass Lee, “Uses and Meanings of Full Social Cost Estimates,” *The Full Costs and Benefits of Transportation*, Springer ([www.springer.de](http://www.springer.de)), 1997, pp. 113-148.

Todd Litman, *Socially Optimal Transport Prices and Markets*, VTPI ([www.vtpi.org](http://www.vtpi.org)), 2000.

Todd Litman, *What's It Worth? Life Cycle and Benefit/Cost Analysis for Evaluating Economic Value*, VTPI ([www.vtpi.org](http://www.vtpi.org)), 2001.

Michael Spackman, Alan Pearman, Larry Phillips, *Multi Criteria Analysis: A Manual*, National Economic Research Associates, DETR ([www.environment.detr.gov.uk/multicriteria](http://www.environment.detr.gov.uk/multicriteria)), 2001.

Transport Policy Section, *External Costs/Benefits: Definition of External Costs and Exogenous Benefits*, Swiss Federal Office for Spatial Development ([www.are.admin.ch/are/en/verkehr/nachhaltige\\_mobilitaet/index.html](http://www.are.admin.ch/are/en/verkehr/nachhaltige_mobilitaet/index.html)), 2004.

TRL, *Strategic Environmental Assessment Newsletter*, Transportation Research Laboratory ([www.trl.co.uk/env\\_sea\\_newsletter.htm](http://www.trl.co.uk/env_sea_newsletter.htm)) provides information on integrated transport planning.

William Vickrey, *Public Economics; Selected Papers by William Vickrey*, Cambridge University Press ([www.uk.cambridge.org](http://www.uk.cambridge.org)), 1994.

VTPI, *Online TDM Encyclopedia*, VTPI ([www.vtpi.org](http://www.vtpi.org)), 2002.

Revised March 18, 2005

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