Transportation Cost Analysis:

Techniques, Estimates and Implications

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Preface

For most of history society's intellectual and industrial resources were devoted to overcoming logistical and technical barriers. Leaders in expanding these limits, Daniel Boone, Thomas Edison, and Henry Ford, are cultural heroes. Progress has eliminated many constraints that faced previous generations. Whipsaws, horse plows and shoe leather have been replaced by chainsaws, tractors, and automobiles, greatly expanding the potential for human control of, and impacts on, the natural and human environment. The question, *What can we do?* is now often replaced by *What should we do?* This presents different but equally challenging problems. This is one way to explain the major changes occurring in the field of transportation planning.

Since transportation systems involve a combination of public and private decisions, transport planning is by nature a political process that involves tradeoffs between stakeholders. It requires effective communication and accurate accounting. Tools to help in this process are relatively new and still under development. For all of its weaknesses, economic analysis offers the potential of addressing the diverse and complex issues that must be considered in transportation decision making.

The basic formal economic evaluation technique, benefit-cost analysis, has been criticized for excluding significant costs, particularly those related to environmental and social impacts. This report explores the potential of incorporating these costs into transport analysis. It attempts to bridge the gap between people who are concerned about qualitative "problems," and those who prefer quantitative economic accounting. Transportation planning and policy making desperately need such tools.

Transportation cost studies frequently begin by acknowledging the tremendous benefits provided by modern transport systems so as not to appear "anti-transport" or "anti-automobile." Consider this done. We all benefit from transportation and many of us delight in using various travel modes. But more is not better. Our transport system can provide even more benefits if costs to users and society are reduced. This study identifies methods for measuring these costs in order to help determine how to optimize our transportation system and avoid squandering valuable resources.

1.0 Introduction

1.1 Study Outline and Scope

This study explores North American roadway transportation costs.[1] It attempts to consider all potential costs, including social and environmental impacts. It investigates the hypothesis that significant costs are commonly ignored in transportation decision making, and explores the implications of such omissions on economic efficiency, equity, and land use patterns.

This first chapter examines the concept of cost and costing methods. Chapter Two reviews and summarizes recent transportation cost studies. In chapters 3.0 through 3.16, sixteen specific transportation costs are defined and discussed, specific existing are reviewed, and "Best Guess" cost values are established for eleven modes under Urban Peak, Urban Off-Peak and Rural travel conditions. Chapter Four summarizes these estimates. Chapter Five considers transportation elasticities and the effects of generated traffic. Chapter Six explores their implications. Chapter Seven examines transportation equity issues. Chapter Eight applies the cost estimates to various policy and planning applications. Chapter Nine summarizes the conclusions of this study and offers recommendations for improving transportation efficiency and equity.

This study's emphasis on costs is not intended to slight the significant benefits of transportation. However, there is an important difference between the allocation of benefits and costs. Most transportation benefits are enjoyed by the user, while many costs are borne by other individuals or society as a whole. These external costs, if they are significant, imply a conflict between individual and societal interests, and indicate the

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[1] Light rail, walking, and telecommuting costs are also estimated for comparison with roadway modes.

likelihood of economic inefficiency and inequity. To appreciate the importance of these costs it is useful to consider situations in which travel activities change in a community and residents must respond to the resulting impacts. For example, imagine that:

- Automobile ownership and travel in your community was expected to double in a few years. What economic, social, health and environmental problems might increase?
- You manage a city that currently has no automobiles. Some citizens want to start using motor vehicles and offer to pay for all costs incurred. The city council asks you to develop a user fee schedule that completely compensates the city and its residents for expenses and damages. What costs would you include? What charges would you recommend for owning a car and driving?
- A new technology eliminates a specific external cost of driving, such as traffic noise or accident risk. How much should the community pay to implement it?

These are slightly exaggerated examples of real issues. This report analyzes transport costs and their implications to help provide answers to these and similar questions.

1.2 Purpose and Context of This Study

This analysis relates to two current trends. The first is a growing concern over social and environmental impacts. There are indications that growing resource consumption and waste production endangers our environment and the quality of our lives. It is important to develop a vocabulary that describes these costs and methods to measure them, preferably in monetary units since economics tends to ignore features that are not priced. *"The market sees only efficiency--it has no organs for hearing, feeling or smelling either justice or sustainability."*[2] Traditional economics does not deny the existence of non-market impacts such as air pollution or habitat destruction, but economic models typically assume that they are small compared with the market costs and benefits.[3] If non-market

[2] Herman Daly and John Cobb, *For the Common Good*, Beacon Press (Boston), 1994, p. 145.
[3] Transportation professionals often refer to environmental and social costs as "intangibles," with the implication that they are subjective and ethereal. With the exception of the remarkable 1975 study *The Full Costs of Urban Transport* by Keeler, et al., and components of the 1982 FHWA *Cost Allocation Study*, transportation professionals did little to quantify or apply these costs until the late 1980's, although

costs are found to be significant then they must be incorporated into transport decision making or even the best intended programs may make society overall worse off.

The second trend is a growing appreciation that motor vehicle traffic must be managed and reduced in urban areas to address congestion and air pollution problems with available financial resources. Transport planning is beginning to consider multimodal, demand management, and land use management solutions to transport problems. These changes require a greater understanding of the impacts of possible policies and investments.

As described in Chapter 2, several previous studies review and even quantify transport costs. This study attempts to incorporate and expand on previous work. It:

- Includes the latest research and cost data.
- Provides a description of the economic theory of prices and costing.
- Covers a broader range of costs than many other studies.
- Creates a framework for using cost estimates in specific policy and planning decisions.
- Applies cost estimates to specific analysis to demonstrate their implications and use.

Psychologists tell us that people's behavior influences their belief.[4] This explains why the debate over transportation costs between modes is often emotional: each user finds arguments to support their own travel choices and habits. Developing objective cost estimates will help create a context of fair and rational debate over the proper planning and investments for each travel mode.

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they expended considerable effort quantifying non-market *benefits* such as travel time savings and accident reduction. To test whether such costs are truly intangible, consider driving an automobile in which air pollution costs are internalized by piping the exhaust directly into the passenger compartment. Even the most skeptical economist will probably agree that environmental costs are quite tangible.

[4] Cy Ulberg, *Psychological Aspects of Mode Choice*, WSDOT (Olympia), 1989, p. 65.

1.3 Defining Transport

How we think about and measure transportation depends on how we define it. Transport is defined as *"To convey from one place to another."*[5] This implies movement or *mobility*. But movement is seldom an end in itself. Even recreational travel is primarily intended to arrive at a destination. The ultimate goal of transportation can be defined as *access*, which is the ability to obtain desired goods, services, and destinations. Over the last century, automobile and truck transport have come to dominate most land transport, so the quantity and speed of motor vehicle traffic have become de facto measures of transport system performance (usually measured as *vehicle miles traveled*, or VMT). But these are imperfect measures of transport quality because:

- In urban areas it is impossible to build enough roads and parking to satisfy all potential automobile trips.
- Some people cannot own or drive a car due to financial, physical, or legal barriers.
- Automobile use imposes increasing financial, environmental, and social costs.

Defining transport as mobility (typically measured as *person mile traveled* or PMT) allows the benefits of non-automotive travel modes such as walking, bicycling, transit, and ride sharing to be recognized. While this is an important step toward expanding the definition of transport, it does not go far enough. If transport is defined by its basic function, *access*, then an even greater range of options can be considered, some of which actually reduce the need for movement.[6] Access is affected by the location of destinations, and availability of substitutes such as communication technology, as well as the ease of travel. Although there is no agreement on how to quantified access, it can be measured based on total transport costs, including travel time. Using this definition, increased travel is not

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[5] *Oxford American Dictionary*, 1980.

[6] Elliot Sclar and K. Schaeffer, *Access For All*, Columbia University Press (NY), 1980; Susan Handy "Highway Blues: Nothing a Little Accessibility Can't Cure," in *Access* (University of California Transportation Center, Berkeley), No. 5, Fall 1994.

necessarily beneficial, it may indicate an overall reduction in access that requires more movement for the same level of benefits.[7] Professor 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."*[8]

David Engwicht develops a similar concept, emphasizing that transport allows *exchange*, and that certain land use, commercial, and social patterns accommodate exchange with more or less ease.[9] The loss of neighborhood stores and delivery services, consolidation of public services such as schools and post offices, and urban sprawl are examples of trends which force people to travel more to obtain access to goods, services and jobs.

1.4 Defining "Cost"

Since this report investigates costs and costing, it is important to define these terms. *Cost* refers to the tradeoffs that individuals and society must make between use of resources. For example, time spent traveling is a *cost* in terms of the opportunity to use that same time in other activities. This same concept applies to the tradeoffs between transport investments and other possible expenditures, between roads and other land uses, and sometimes between transportation activities and environmental protection.

The terms *cost* and *price* are often used interchangeably, but in formal economics *cost* is defined broadly as any "benefits foregone." This can involve money, time and other resources, or the loss of an opportunity to enjoy a benefit. Price usually refers specifically to market costs. 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*

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[7] Reid Ewing, "Transportation Services Standards - As If People Matter," *Transportation Research*, 1/93
[8] John Whitehead, "Time Pollution," *The Ecologist*, Vol. 23, No. 4, July 1993, p. 131.
[9] David Engwicht, *Reclaiming Our Cities and Towns*, New Society Publishing (Philadelphia), 1993.

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."[10]

Because of their mirror-image relationship, measuring costs often begins by defining a benefit foregone, while benefits are defined by reduced costs. *Costing* (also called *monetization*) involves quantifying these in monetary units. Important distinctions include:

1. *Internal and External Costs*

Costs can be divided between *internal* (also called *user*) and *external* (also called *social*) costs. Internal costs are borne by the good's consumer. External costs are borne by others, either individuals or society as a whole. Some costs are external to individual users but borne by the sector (group) as a whole. For example, accident costs that are compensated by liability insurance are external to the individual who has the accident, but internal to all drivers who buy insurance. Which standard should be used to define externalities in a particular analysis depends on the type of problem being addressed. If the concern is equity ("People shouldn't have to pay for something they don't use.") then costs need only be internalized at the sector level. If the concern is economic efficiency ("People tend to squander resources that they get for free."), then costs must be internalized at the individual level in order to give users correct economic incentives. An external cost can be internalized if the user adequately compensates those on whom the cost is imposed. If the injured party does not consider the compensation "worth" the damage suffered, the cost is only partially internalized.

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[10] Douglass Lee, *Full Cost Pricing of Highways*, Na. Transport Systems Center (Cambridge), 1995, p. 7.

2. *Variable (Marginal) and Fixed Costs*

Variable costs are proportional to consumption. Fuel, travel time and accident risk are variable automobile costs. Fixed costs do not vary with use, such as depreciation, insurance, and registration. The distinction between fixed and variable often depends on the perspective and time horizon. For example, depreciation is often considered a fixed cost because car owners make the same payments no matter how many miles a year they drive; but a car's operating life and resale value are affected by how much it is driven, so depreciation is partly variable. Variable costs are also called *marginal* costs, defined as the cost of an additional unit. Past and fixed costs are considered *sunk*.

3. *Perceived and Actual Costs*

There is often a difference between perceived and actual automobile costs. Users tend to be most aware of immediate costs such as travel time, stress, parking fees, fuel, and transit fares, while costs that are only paid occasionally, such as insurance, registration, and maintenance are often underestimated.[11] Some costs tend to be ignored by users altogether, such as parking subsidies and external environmental impacts.

4. *Market and Non-Market Costs*

Costs can also be divided between *market* and *non-market*. Market costs involve goods that are regularly traded in a competitive market, such as land, cars, and gasoline. Non-market costs involve goods that are not regularly traded in markets such as clean air, accident risk, and quiet. Although many non-market goods have significant value, they are often ignored or underestimated compared with market costs.

5. *Direct and Indirect Costs*

A fifth consideration is the degree to which costs are *direct* or *indirect*. Quantifying indirect costs and benefits requires an understanding of the various steps connecting an

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[11] Cy Ulberg, *Psychological Aspects of Mode Choice*, WSDOT (Olympia), 1989, p. 20.

activity with its ultimate effects. Whether an activity imposes an indirect cost can be determined using a "*with and without*" test.[12] The difference in impacts with and without a project or policy are considered a result of that project or policy. For example, the negative effects of land use changes resulting from a transportation project that would not otherwise occur should be considered a cost of that project.

An important indirect and long term impact of automobile use is a greater dispersion of land uses which increases the need to travel in order to maintain access to goods and services, and a non-automotive reduction in travel alternatives. This is called *automobile dependency*,[13] and will be discussed further in chapters 3.9, 3.14, and 7.

Costs -- A Primer

Consider the costs of owning a pet dog. A dog can often be obtained for a low *price* or even for free. But pet owners quickly discover that a dog imposes 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*. These non-market costs can 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 or breed. Some costs are not separate expenses; they are price *premiums* or extra costs to other expenditures, such as more frequent rug cleaning, or the added cost of a larger back 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.

Table 1-1 shows examples of motor vehicle costs indicating major categories.[14]

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[12] C. van Kooten, *Land Resource Economics and Sustainable Dev.*, UBC Press (Vancouver), 1993, p. 86.
[13] Newman and Kenworthy, *Cities and Automobile Dependency*, Gower Press (Aldershot), 1989.
[14] Of course, these categories are general, not absolute. There are exceptions to these allocations.

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

	Variable	Fixed
Internal (User)	Fuel Short term parking Vehicle maintenance (part) *User time & stress* *User accident risk*	Vehicle purchase Vehicle registration Insurance payments Long-term parking facilities Vehicle maintenance (part)
External (Social)	Road maintenance Traffic law enforcement Insurance disbursements *Congestion delays* *Environmental impacts* *Uncompensated accident risk*	Road construction "Free" or subsidized parking Traffic planning Street lighting *Land use impacts* *Social inequity*

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

These various cost distinctions have significant effects on decision making. Consumers base decisions primarily on perceived internal variable costs. Automobile owners decide how often and how far to drive based primarily on perceived internal short-run variable costs. Public agencies tend to be influenced by perceived costs to their constituents, however defined. Current transport planning and investment decisions focus on short- and medium term direct market costs.

Ideally, public planning and investment analysis should consider *all* marginal costs, including long-term, non-market and indirect costs. Since transport planning is based on time horizons of many years or even decades, virtually all costs can be considered marginal, including vehicle ownership, roads, parking facilities.

1.5 Treatment of Taxes

Taxes require special consideration in cost analysis. Economists usually consider taxes to be transfer payments, not costs, and net them out before calculating costs and benefits.[15] However, fuel taxes and other charges dedicated to roadway facilities are often considered

[15] Ian Heggie and Simon Thomas, "Economic Considerations," *Transportation and Traffic Engineering Handbook*, Institute of Transportation Engineers/Prentice Hall (Englewood Cliffs, NJ), 1982, p. 426.

user fees, and are frequently treated as such in economic analyses. Also, when one activity is exempted from a broad based tax, it can be treated as an expenditure.[16] 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."*[17] Examples of this include exemptions of general sales taxes on motor vehicle fuel, unique petroleum industry tax loop holes, and the exemption of roadway rights-of-way from property taxes, each of which is discussed later in this report.

1.6 Discount Rate in Cost Analysis

Discount rates affect calculations of future costs and benefits. Discount rates reflect the time value of money, which assumes that wealth can be invested to generate a profit, so current resources have greater value than future resources, even after adjusting for inflation. Discount rates that include inflation are referred to as *nominal* discount rates, while those that are net of inflation are called *real* discount rates. Selecting the correct discount rate is important when assessing environmental costs and benefits that may occur decades or generations in the future. The higher the rate, the more weight is given to present over future benefits. Capital investment discount rates are typically 8-10%. These rates reflect the return capital could earn in typical alternative investments.

A debate now exists as to the discount rate to use for human health and environmental costs imposed on future generations.[18] Conventional discounting implies that costs many years in the future are of little concern now.[19] For example, at an 8% discount rate, costs

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[16] Examples include Apogee Research, 1993, p.9; Ridgeway, 1990, p. 14; Hubbard, 1991, p. 21.
[17] Douglass Lee, *Full Cost Pricing of Highways*, Na. Transport Systems Center (Cambridge), 1995, p. 31.
[18] C. van Kooten, *Land Resource Economics and Sustainable Development*, UBC Press (Vancouver), 1993, p. 96.
[19] One justification for discounting costs imposed on future generations is the assumption that they will be wealthier, on average, than current generations. In recent years this assumption has been challenged. Herman Daly, Paul Erlich and others argue that future generations may have less wealth than we do.

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, and do not reflect society's desire to provide a better world for our descendants. They recommend using a 0-4% discount rate for human health and environmental costs and benefits to give fair consideration to future generations' interests.[20]

1.7 Pricing Non-Market Goods[21]

Including non-market costs in public decision making is challenging but important. Excluding them skews decisions toward options with high environmental and social impacts. The transport planning profession uses established values for travel time savings and accident reductions for investment analysis. This study expands the list of non-market goods that are monetized to include environmental and social costs.

Assigning monetary values to nonmarket goods can improve planning and policy making. It facilitates fairness and economic efficiency. For example, it would be unfair and inefficient if one firm or sector was required to spend $2,000 per ton of NOx reduction while another firm producing comparable emission spends significantly less. Greater total benefit may be achieved by shifting resources to the more cost effective option. Of course, there are situations in which different unit costs for environmental protection are justified, for example, to place a greater burden on firms with more resources, but these should be conscious decisions. This requires that the cost per unit of benefit be determined as a reference, which is essentially monetization.

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[20] Robert Costanza and Herman Daly, "Natural Capital," *Conservation Biology*, Vol. 6, No. 1, Mar. 1992.
[21] David Pearce, *Economic Values and the Natural World*, MIT Press (Cambridge), 1993; Ismail Seregeldin, Ed., *Valuing the Environment*, World Bank, Washington DC, 1994; Nick Hanley and Clive Spash, *Cost-Benefit Analysis and the Environment*, Edward Elgar (Brookfield), 1993; David James, *The Application of Economic Techniques in Environmental Impact Assessment*, Kluwer (Boston), 1994.

There is nothing unusual or mysterious about valuing non-market goods. Individuals and public officials often make decisions which trade non-market goods, such as clean air, quiet, and wilderness preservation, against money or market goods. For example:

- Home buyers must decide how much extra they will pay (in dollars or by giving up other amenities) for a residence that is subject to less noise or air pollution.
- Public agencies must decide how much society should spend (either in direct expenditures or by giving up other benefits) to achieve goals such as improved air quality, reduced accident risk, or increased speed and comfort for drivers.
- Individuals choose how much to spend to avoid a hazard (such as using a longer but safer travel route), obtaining safety (such as buying the latest automotive safety equipment), or how much compensation they require to work at a dangerous job.

When numerous transactions involving trades between market and non-market goods are performed it is possible to identify patterns that effectively determine the price paid for the non-market good. In recent years a number of methods have been developed to measure in monetary units the value that society is willing to pay for non-market goods. Monetization of non-market goods is becoming increasingly common in a number of fields including energy planning, injury compensation, and environmental policy analysis. There are five general techniques for monetizing non-market costs:[22]

1. *Hedonic Methods* (also called *Revealed Preference*)

   Hedonic pricing infers values for non-market goods from their effect on market prices. A common strategy is to analyze the effects of impacts on property values and wages. For example, if houses on streets with heavy traffic are valued lower than otherwise comparable houses on low traffic streets, the cost of traffic (or, conversely, the value of neighborhood quiet, clean air, safety, and privacy) can be calculated.

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[22] Kenneth Button, "Overview of Internalising the Social Costs of Transport," in *Internalising the Social Costs of Transport*, OECD (Paris), 1994, p. 17.

2. *Control* or *Prevention Costs*

A cost can be estimated based on prevention, control or mitigation expenses. For example, if industry is required to spend $1,000 per ton to reduce an air pollutant, we can infer that society considers that emission to impose costs at least that high.

3. *Contingent Valuation* (also called *Stated Preference*)

Contingent valuation infers costs by surveying a representative sample of society how much they value a particular non-market good. For example, residents may be asked how much they would be willing to pay for a certain improvement in air quality, or an acceptable minimal compensation for the loss of a recreational site. Such surveys must be carefully structured and interpreted to obtain accurate results.

4. *Precedents*.

This uses policy and legal judgments as a reference for assessing non-market costs.

5. *Travel Cost*

This method uses visitors' travel costs (monetary expenses and time) to measure consumer surplus provided by a recreation site such as a park or other public lands.

A high standard of protection of possible irreversible losses to future generations is often supported based on the *precautionary principle*.[23] Protection against such losses may add *option value* to an environmental good's direct benefits.[24] Examples of irreversible impacts include species extinction and climate change. Even the cutting of old growth forest or draining a wetlands may be irreversible within the time frame of human lifetimes.

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[23] 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.

[24] Hanley and Spash, *Cost-Benefit Analysis and the Environment*, Edward Elgar (Brookfield) p. 153.

1.8 Criticism of Transportation Cost Analysis

The analysis in this report tends to be criticized from two perspectives. One is from transportation professionals and automobile industry advocates who argue that too much emphasis is placed on costs without acknowledging the benefits provided by our transportation system.[25] When confronted with evidence of external transportation costs their reaction to costs tends to follow the following progression:

1. "The cost does not exist."
2. "It may exist, but is not significant."
3. "It may be significant, but is not related to driving."
4. "It may be related to driving, but cannot be quantified."
5. "It may be quantified, but incorporated it into decision making is impractical."
6. "It may be incorporated in decisions, but to do so would not be politically acceptable."
7. "Benefits to society surely outweigh this cost."

The response to points 1-5 rests on the strength of each analysis to demonstrate that a particular cost exists, that it may be significant compared with costs currently considered in transport planning, that transportation contributes to it, and that methods exist to measure it. Since these are relatively new fields of research there is still uncertainty about some cost estimates, resulting in the recommendation, universal to all such studies, that further research is needed. However, a major reason that transportation decision makers are not aware of the full range of external costs, and fail to use monetized estimates of non-market costs in planning and investment analysis is simply that they have made little effort to learn about current research in these field or to expand existing data to fill gaps.

Points 6 and 7 require a different response. A discussion of costs does not deny political realities or the existence of benefits. It does, however, allow society to be more conscious and precise in decision making so that the maximum benefits can be achieved. It would be

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[25] See for example Eric Beshers, *External Costs of Automobile Travel and Appropriate Policy Responses*, Highway Users Federation (Washington DC), March 1994. Contact the author of this report for his responses to Beshers' analysis of external transportation costs.

irresponsible to provide a blank check for the purchase of any good, no matter how beneficial, which is implied in arguments that, *"Benefits surely outweigh the costs."*

The second type of criticism typically comes from environmentalists who consider economics in general, and the monetization of non-market goods in particular, to be reductionist and inappropriate. Conventional economic models assume that people are simply selfish consumers, that all resources are commodities, and that market activity defines society's well being. These assumptions are clearly wrong. It is incumbent on economics to incorporate a broader view of humanity, society and the environment. In recent years the field of ecological economics has developed a vocabulary that reflects society's non-commercial aspirations such as generosity, cooperation, and spirituality. We can now discuss, for example, the existence value that people place on sacred objects, and the importance of option and bequest values.[26] Of course, there is still uncertainty concerning these concepts and methods, and many economists do not acknowledge or understand them, but the potential exists for economics to address the criticisms raised.

Readers who are uncomfortable with formal economics may prefer to mentally replace the word "cost" with the word "problem" when it appears in this report. Thus the question, *"Is automobile air pollution a cost?"* becomes, *"Is automobile air pollution a problem?"* But after reviewing the various problems (costs) readers may become curious about their relative magnitude. *"Is this problem significant?" "How does it compare with other problems?"* These lines of inquiry return us to the concept of costs (benefits foregone), and the usefulness of quantitative estimates. We might begin by assigning degrees of "badness" (*"Air pollution is a 10 on the badness scale, and traffic noise is a 6."*), but if any such cost can be valued in dollar units, it becomes possible to monetize them all, based

[26] Existence value is the value people place on resources or goods that they but do not use directly but wish to preserve. Option value is the value of retaining a choice even if it is not immediately used. Bequest value reflects the desire of individuals to provide goods and benefits to future generations.

on relative "badness." Monetized costs, it turns out, are useful references that are already widely used in various types of decision making.

1.9 Treatment of Variability and Uncertainty

The cost estimates provided in this and other reports are generic values. Of course, there is considerable variability depending on many factors, including location, time, vehicle type, and driver behavior. Ideally, the cost values presented here would be modified as appropriate before they are used in specific planning applications. For example, if you are calculating parking cost savings that would result from increased transit commuting in your community, you should consider whether your community has a shortage of parking spaces, whether this problem is increasing or decreasing, whether the commuters who would shift to transit are more or less likely than average to receive free parking, and whether parking facility costs are higher or lower than average in your area. Depending on your time, resources and needs, you can use the generic numbers from this report as they are, do a spot check to identify any significant variations from national averages, or perform a study of this cost specific to your circumstances, in which case this report can serve as a reference for your research.

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. As stated by Professor Richard Ottinger, an expert in environmental 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."*[27]

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[27] Richard Ottinger, "Incorporating Externalities - The Wave of the Future," in *Expert Workshop on Lifecycle Analysis of Energy Systems*, OECD (Paris), 1993, p. 54.

A common way to deal with uncertainty in economic analysis is to include only costs that are commonly accepted and easily quantified. If a cost is difficult to measure, it is often ignored, even if it is probably comparable in magnitude to other costs.[28] Excluding or using low estimates of costs that incorporate uncertainty is often defended as being "conservative," implying that this approach is cautious.

The use of the word *conservative* in this context is confusing because it results in the opposite of what is implied. Low *cost* estimates result in undervaluing damages and risks, thereby overvaluing relative benefits and assets, which is less cautious and less conservative in accounting terms. Accountants prefer to use high estimates of risks and losses and low estimates of benefits and assets when uncertainty exists in order to avoid careless optimism. For example, if different assessments are made of an asset's value, an accountant should generally use the lower estimate for calculating net worth because most individuals and businesses can handle an unexpected abundance of wealth better than its unexpected absence.

When economists call low estimates of costs *conservative* they are actually using the word in its political meaning of maintaining the status quo, not the conservation of resources. In practice, low estimates of non-market and indirect costs leads to increased social and environmental damages since these have only recently been included in economic analysis. For example, a low estimate of air pollution costs will reduce the justification for investing in emission control efforts, resulting in more pollution and less conservation of natural resources. In other words, excluding or undervaluing these costs result in *less* conservative and cautious analysis results.

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[28] These "intangible" costs are often addressed through a separate part of the transportation planning process, such as an environmental assessment or through public participation. But such a duel track tends to underweigh non-market values and provides little help to planners and designers in making tradeoffs.

Another way to deal with uncertainty is to use a range of costs rather than a point estimate. For this reason minimum and maximum estimates of average automobile costs are provided in chapters 3.1 to 3.16 to facilitate sensitivity analysis. However, establishing ranges requires the same estimation methods as a point estimate, so this approach doesn't completely solve the uncertainty problem. It should be understood that all point estimates represent a range of values that depend on time, place, and other variables and uncertainties.

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, and the resulting estimate is within the expected range with respect to other costs. Assuming that the variation among the uncertainty is random, the over- and under-estimates among these estimates will tend to cancel each other out. Including such estimates is more accurate and more conservative than setting their value at zero, which consistently underestimates total costs.

2.0 Transportation Cost Literature Review

Several previous studies describe, assess, and calculate transportation costs, encompassing a wide range of perspectives and techniques. Many address only one or two costs. A few attempt to be more comprehensive but include no original material or perspective. Seventeen cost studies summarized in this chapter were selected because they include at least some original research, are comprehensive, or because they represent a unique perspective. Taken together, the 17 studies indicate current knowledge and trends in this field. Table 2-10 at the end of this chapter summarizes the costs in these various studies.

1. *The Full Costs of Urban Transport; Intermodal Comparisons* (1975) by Keeler, et al. This report summarizes research by transport economists at the Institute of Urban and Regional Development, comparing commuting costs of automobile, bus and rail in the San Francisco Bay area. It includes calculations of marginal congestion costs, public services, noise, air pollution, facilities, accidents, parking, and user costs. This is the oldest study of its type. The analysis is still highly regarded.

2. *Transportation Efficiency: Tackling Southern California's Air Pollution and Congestion*, (March, 1991) by Michael Cameron, published by the Environmental Defense Fund. This study uses estimates of external transportation costs to argue for pricing as a strategy for demand management. External costs include air pollution, congestion, and parking. The recent follow-up study, *Efficiency and Fairness on the Road*, (March 1994) by the same writer and publisher, extends this research to cover transportation policy equity impacts.

3. *The Costs of the Car: A Preliminary Study of the Environmental and Social Costs Associated with Private Car Use in Ontario*, (October 1991), by Pollution Probe, an environmental

organization in Toronto. This critique of automobile use and the automobile industry covers a large number of costs, as described in Table 2-1.

Table 2-1 **"The Costs of the Car" Cost Categories**

Land Use	Environmental	Human Health	Social
Highway expenditures. Destruction of agricultural land and urban greenspace. Excessive energy consumption.	Government environmental expenditures. Mining. Metal smelting. Energy use. Petroleum industry. Air pollutants. Maintenance of a car-centered infrastructure. Disposal.	Road safety expenditures. Health care costs. NOx, VOCs and Ozone. Carbon Monoxide. Lead. Water pollution. Ozone depletion. Global warming.	Policing. Court costs. Congestion and lost time. Stress and decline in quality of life. The transportation disadvantaged. Death and injury.

4. *Making Transportation Choices Based on Real Costs*, (1991) by Brian Ketcham. This paper includes monetized estimates for air pollution, noise and vibration damage, pavement wear and indirect damage to other vehicles, congestion costs, and traffic accidents. Also mentioned but not quantified are water pollution, oil spills, global air pollution, roadway and parking land value, petroleum import costs, vehicle production, and waste disposal external costs.

5. *Results of Literature Survey and Summary of Findings: The Nature and Magnitude of Social Costs of Urban Roadway Use* (July 1992) by Mark Hanson, published by the U.S. Federal Highway Administration. This study identifies external costs of urban roadway transportation and describes costing methods. It also includes recommendations for better calculating external costs, incorporating costs into user prices, and applying least-cost planning to transportation.

6. Kjartan Saelensminde's *Environmental Costs Caused by Road Traffic in Urban Areas - Results from Previous Studies* (1992), published by the Institute for Transport Economics in Oslo, Norway. This study focuses on three costs of urban road transport: air pollution, noise, and the barrier effect. Table 2-2 summarizes these costs for Norway.

Table 2-2 **Costs of Noise, Air Pollution and Barrier Effects Due to Road Traffic in Urban Areas.**

	Cost Per Person		**Total Costs in Norway**	
	NOK/Year	**US$/Year**	**Million NOK/Year**	**Million US$/Year**
Noise	600-3,700	88 - 541	180-1,110	26 - 162
Air Pollution	5,100-26,000	746 - 3,802	770-3,900	112 - 569
Barrier Effect[1]	767	112	3,300	483

NOK = Norwegian Kronor

7. *The Going Rate*, 1992, by James MacKenzie, Roger Dower, and Donald Chen for the World Resources Institute. A comprehensive study of U.S. motor vehicle costs. Cost categories include roadway facilities and services, parking, air pollution and global warming, security costs of importing oil, congestion, motor vehicle accidents, noise, and land loss. The report's conclusion that driving incurs as much as $300 billion in external costs each year is widely quoted.

8. *Getting the Prices Right; A European Scheme for Making Transport Pay its True Costs*, (1993) by Per Kågeson, for the European Federation for Transport and Environment. This study estimates pollution, accident and infrastructure costs in European countries. Cost summaries for the UK are shown in Table 2-3. Similar estimates are made for other European countries.

Table 2-3 **External Transport Costs (ECU/1000 passenger km)**

Mode	**Air pollution**	**CO_2**	**Noise**	**Accidents**	**Total**	**Total ($/mile)**
Car	14.6	4.5	0.9	8.9	28.9	$0.060
Electric train	0.9	2.2	0.2	3.8	7.1	$0.015
Aircraft	7.3	9.2	1.2	0.2	17.9	$0.037

9. *The Cost of Transporting People in the British Columbia Lower Mainland* (March 1993), by Peat Marwick Stevenson & Kellogg for Transport 2021, a planning effort for the Vancouver region. This study develops cost estimates for 12 modes using local research and generic estimates. Costs included in the study are listed in Table 2-4.

[1] The *barrier effect* is discussed in chapter 3.13.

Table 2-4 **Costs of Transporting People in B.C. Costs**

Direct User	Indirect Parking	Transport Infrastructure	Time	Urban Sprawl	Environmental and Social
Fixed vehicle costs. Variable vehicle costs. Parking fees.	Residential. Commercial. Government.	Road construction. Road maintenance. Road land value. Transit land value. Protection services.	Personal. Commercial delays.	Infrastructure. Loss of open space. Future transport.	Unaccounted accident costs. Air pollution. Noise pollution. water pollution.

10. *Land Transport Externalities* (1993), by Works Consultancy Services for Transit New Zealand. This comprehensive and well-researched study is part of New Zealand's efforts to rationalize transport planning, and possibly implement road pricing. It attempts to describe all external costs of roadway transportation and identify costing methodologies. Cost categories are shown in Table 2-5. Cost estimates will be developed in future reports.

Table 2-5 **Works Consultancy Cost Categories**

Pollution Effects	Intrusion Effects	Interference Effects	Urban Form and Land Use
Air Pollution & Dust Impacts on the Global Atmosphere Effects on Water Systems Noise & Vibration Disposal of Waste	Visual Effects Habitat impacts. Effects on Landscape Archaeological Sites Cultural & Spiritual Effects Recreational Effects Strategic Effects	Community Disruption Urban and Rural Blight and Stress of Change Lighting Effects Community Severance and Accessibility Hazard Effects	

11. *The Price of Mobility* (October, 1993), by Peter Miller and John Moffet, published by the Natural Resources Defense Council. It attempts to quantify total annual U.S. costs for automobile, bus, and rail transport. It is one of the most comprehensive efforts in terms of costs described and quantified for these three travel modes. Costs included are listed in Table 2-6.

Table 2-6 **The Full Cost of Transportation in the U.S.A.**

Personal	Government Subsidies	Societal	Unquantified
Automobile ownership. Transit fares.	Capital and operating. Local government.	Energy. Congestion. Parking. Accidents. Noise. Vibration. Air pollution. Water pollution.	Wetland lost. Farmland lost. Historic property. Property value impacts. Inequity. Sprawl.

12. *The Costs of Transportation: Final Report* (March 1994), by Apogee Research for the Conservation Law Foundation. This estimates user, accident, congestion, parking, road facilities and services, air pollution, water pollution, energy, and noise costs. Some additional costs, such as urban sprawl and aesthetic degradation are mentioned but not estimated. A costing model is developed which calculates the total cost of trips by nine modes, in three levels of urban density, during both peak and off-peak periods. This model is applied to case studies of Boston and Portland, Maine urban travel costs.

Table 2-7 **Federal Railroad Administration Costs**

Social Costs				
Land Use	**Community Disruption**	**Energy**	**Safety**	**Congestion**
Direct land use for facilities. Alters land use patterns (sprawl).	Divides community. Impacts local government. Visual pollution. Relocation impacts.	Oil spills. Air pollution. Political instability from foreign oil. Oil price fluctuations affecting world economy.	Accidents cause death, injuries, insurance and legal costs, lost productivity, medical costs, emotional losses, congestion.	Wasted time. Wasted fuel. Added pollution. Lost productivity. Vehicle repair and insurance costs. Stress. Land use impacts.
Environmental Costs				
Air	**Noise**	**Water**	**(Electromagnetic Fields (EMF)**	**Hazardous Materials**
Carbon Monoxide. VOCs. SO^2. NOx. CO^2. Air Toxics. Particulates. CFCs. Odor.	Construction/ repair. Night operations. Engines Wheels/tires. Congestion. Braking/ acceleration Idling. Whistles.	Air pollution fallout. Fuel releases and spills. Construction/ maintenance. De-icing. Runoff from roads and parking lots.	(Cost of electric vehicles.) Possible biological hazard. Possible hazard to migrating birds. Problems to electronic equipment.	Accidental releases. Intentional releases.

13. *Environmental Externalities and Social Costs of Transportation Systems - Measurement, Mitigation and Costing: An Annotated Bibliography* (August 1993), USDOT, Federal Railroad Administration, Office of Policy. This bibliography describes recent publications on

transportation costing. It includes two charts that describe a taxonomy of costs and mitigation strategies, summarized in Table 2-7.

14. *Full Cost Pricing of Highways* (January 1995), Douglass Lee, USDOT Volpe National Transportation Systems Center, Cambridge. This study analyzes optimal pricing for economic efficiency. Table 2-8 summarizes Lee's estimates of external costs.

Table 2-8 **Estimates of Highway Costs Not Recovered From Users**

Cost Group	Cost Items	Estimate
Highway Capital	Land (interest)	$74,705
	Construction:	
	Capital Expenditures	42,461
	Interest	26,255
	Land acquisition and clearance	
	Relocation of prior uses and residents	
	Neighborhood Disruption	
	Removal of wetlands, acquirer recharge	
	Uncontrolled construction noise, dust and runoff	
	Heat island effect	
Highway Maintenance	Pavement, ROW, and structure maintenance	20,420
Administration	Administration and research	6,876
	Traffic police	7,756
Parking	Commuting	52,877
	Shopping, recreation, services	14,890
	Environmental degradation	
Vehicle Ownership	Disposal of scrapped or abandoned vehicles	706
Vehicle Operation	Pollution from tires	3,000
	Pollution from used oil and lubricants	408
	Pollution from toxic materials	1
Fuel and Oil	Strategic Petroleum Reserve	4,365
	Tax subsidies to production	9,000
Accidental Loss	Government compensation for natural disaster	
	Public medical costs	8,535
	Uncompensated losses	5,850
Pollution	Air	43,444
	Water	10,861
	Noise and vibration	6,443
	Noise barriers	5,117
Social Overhead	Local fuel sales tax exemptions	4,302
	Federal gasohol exemption	1,129
	Federal corporate income tax	3,389
	State government sales taxes	13,218
	Local government property taxes	15,962
	Total	$382,134
	Current User Revenues	52,096
	Loss	330,037
	cents/VMT	$0.152

15. "The Costing and Costs of Transport Externalities: A Review," *Victorian Transport Externalities Study*, Environment Protection Authority (EPA), Melbourne, Australia, 1994. This report discusses external cost implications, reviews costing methods, and estimates noise, air emissions, accidents, and congestion costs.

16. *Comparing Multi-Modal Alternatives in Major Travel Corridors*, (January 1994), by Patrick DeCorla-Souza and Ronald Jensen-Fisher. This paper compares total costs of highway, bus, and subway investments. Costs included are listed in Table 2-9.

Table 2-9 **DeCorla-Souza and Jensen-Fisher Cost Estimates**

Vehicle	Highway	Public Transport	Safety and Security	Travel Time	Environ-mental	Accidents
Operating. Ownership. Parking.	Operation & Maintenance Capacity	Bus system. Subway system.	Public services Accident (market).	Travel time.	Air & Water. Noise. Waste.	Accidents (non-market).

17. *Saving Energy In U.S. Transportation*, Office of Technology Assessment, July 1994. This study includes estimates of total U.S. motor vehicle costs based on preliminary results of an extensive research project by Mark DeLuchi of UC at Davis. Updated cost estimates are scheduled for release by DeLuchi in 1995.

18. *External Costs of Truck and Train*, Transport Concepts, for the Brotherhood of Maintenance of Way Employees, October 1994. This study compares external costs of train versus truck freight transport to justify increased truck taxes or increased subsidies for rail transport. Table 2-10 summarizes their results.

Table 2-10 **External Costs of Train Vs. Bus** (1994 Canadian Cents per Tonne Kilometer)

Cost	Intercity Truck Average	Truck Semi Trailer	Truck B-Train	Rail System Average	Rail Piggy Back	Rail Con-tainer	Rail Box Car	Rail Hopper Car
Accidents	0.40	0.40	0.40	0.06	0.06	0.06	0.06	0.06
Pollution	0.71	0.72	0.58	0.23	0.36	0.29	0.25	0.15
Interference (congestion)	0.64	0.65	0.52	-	-	-	-	-
Infrastructure	0.67	0.69	0.52	-	-	-	-	-
Cash Subsidy	0.09	-	-	0.28	0	0	0	0
Cost Subtotal	2.51	2.46	2.02	0.57	0.42	0.35	0.31	0.21
Fuel Taxes	-0.29	-0.29	-0.22	-0.06	-0.09	-0.07	-0.04	-0.04
License Fees	-0.07	-0.07	-0.07	-	-	-	-	-
Revenue Subtotal	-0.36	-0.36	-0.29	-0.06	-0.09	-0.07	-0.04	-0.04
Net External Costs	2.15	2.10	1.73	0.51	0.33	0.28	0.27	0.17

19. *Transportation Sector Subsidies; U.S. Case Studies*, DRI/McGraw-Hill for the U.S. Environmental Protection Agency, Energy Policy Branch (Washington DC), November 1994. This report summarizes existing estimates of external costs including air pollution (local and global), congestion, accidents, noise and vibration for rural and urban automobile and truck use. It estimates the macroeconomic effects of implementing various pricing strategies to internalize costs and reducing CO_2 emissions.

Cost Estimates Summarized

Table 2-10 summarizes the transportation cost studies, identifying costs that are either described or estimated in each report. These studies show the range of perspectives and efforts exploring transportation costs.

Table 2-10 **Transport Costs in Current Literature (C = Costed; D = Described)**

Study No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Cost Categories	Keeler	Cam-eron, EDF	Pol. Probe	Ket-cham	Han-son	Saelen sminde	Mac Kenzie	Kåg-eson	PMSK	Works, N.Z.	Miller, Moffet	Apo-gee, CLF	US DOT, FHWA	Doug Lee,	EPA, Aust.	De Corla Souza	OTA	Tran. Conc.	DRI/ MG , EPA
Vehicle Costs	C		D					D	C		C	C		D		C	C		
Travel Time	C		D					D	C			C		D		C	C		
Accidents	C		D	C	D		C	C	C		C	C	D	D	C	C	C	C	C
Parking	C	C			D		C		C		C	C		D		C	C		D
Congestion	C	C	D	C	D		C	D	C		C	C	D	D	C	C	C	C	C
Facilities	C		D	C	D		C	C	C		C	C		D		C	C	C	C
Roadway Land	C				D		D		C		D	C		D			C	D	
Mun. Services	C		D		D		C	D	C		C	C		D			C	D	
Air Pollution Local	C	C	D	C	D	C	C	C	C	D	C	C	D	D	C	C	C	C	C
Air Pollution Global			D	D	D		C	C		D	C	C	D	D			C	C	C
Noise&Vibration	C		D	C	D	C	C	C	C	D	C	C	D	D	C	C	C	C	C
Resources/ Energy			D	C	D		C		C	D	C	C	D	D		C	C		
Barrier Effect			D		D	C		D		D				D					
Land Use/Sprawl			D					D	C	D	D	D		D					
Inequity		D	D	D							D								
Water			D	D	D			D	C	D	C	C	D	D		C	C	D	
Waste Disposal			D	D						D				D		C	C		
Historic Artifacts										D	D		D						

3.0 Definitions, Costing Methods, and Estimates

Each of the next 16 chapters (3.1 through 3.16) defines, describes, and estimates a specific road transport cost. Costs are valued in 1994 U.S. dollars and units (mile, foot, U.S. gallon) except where noted otherwise. *Best Guess* cost estimates are provided for eleven modes under Urban Peak, Urban Off-Peak, and Rural travel conditions.[1] The distribution of driving between these travel conditions is shown in Table 3-1. Minimum, maximum and weighted average costs are also provided.

Table 3-1 **Estimated 1993 U.S. Vehicle Miles Traveled (VMT)[2]**

	VMT (billions)	Percent of Total
Urban Peak	460	20%
Urban Off-Peak	920	40%
Rural	920	40%
Total	2,300	100%

This table shows how U.S. trips are divided into three travel conditions in this report.

These Best Guess estimates are either dollars per vehicle mile or per passenger mile, depending on what is most appropriate for each cost. In a separate spreadsheet these values are converted into dollars per passenger mile based on average passenger rates, to create a fair comparison between modes. These values are the basis for cost comparisons summarized in Chapter 4, and a variety of analysis in chapters 5, 6 and 7.

Cost Chapter Sections
The following 16 chapters include these sections:

Definition: Defines the cost for this analysis.

Description: Describes the cost as it typically applies. (This is not needed for all costs)

Discussion: The existence of each cost, its relationship to transport activities and specific modes are explored, and useful background information is provided.

[1] Urban includes suburban areas, since they experience congestion, parking, environmental, and municipal service costs similar to denser urban areas.
[2] *Facts and Figures 93*, Motor Vehicle Manufacturers Association (Detroit), p. 62, assuming 3% annual growth in VMT since 1992. Percent Urban Peak is estimated.

Estimates: Existing estimates of this cost are summarized, and in some cases an original estimate is provided.

Variability: Factors that may affect this cost are described.

Conclusions: The cost is summarized and a *Best Guess* estimate per vehicle mile is made for the 11 modes under Urban Peak, Urban Off-Peak, and Rural conditions. The weighted average of these three conditions (based on mileage estimates in Table 3-1) is also listed.

Automobile Cost Range: Minimum and Maximum costs are defined for Average Automobile travel.[3] This is based on the highest and lowest reasonable estimates.

In this analysis Urban Peak travel is generally used interchangeably with commuting. In recent years travel surveys have started counting each link of a trip separately. As a result, statistics now indicate that a majority of peak period travel is not considered commuting. However, many links not officially considered commute trips are part of the overall trip between home and work, such as stops at a daycare center or store. Survey data indicates that work trips account for 21.6% of all personal trips, while chained trips related to commutes represent 30% of personal trips.[4] These are all considered commute trip in this analysis since their scheduling and direction are generally determined by employment.

The transportation cost framework and specific cost estimates described here can be used in many specific analyses. Some examples are explored in Chapter 6. Since these cost estimates are generic, representing overall North American averages, ideally they should be adjusted and updated to specific applications. For example, parking facility costs may be higher or lower in specific situations than these estimates due to variations in real estate values, rates of free parking, and ratio of parking spaces per vehicle. This framework can also be expanded to include additional modes or travel situations, such as intercity passenger rail, or alternative fuels. Users can adjust or expand these cost estimates as necessary, taking care to be consistent with the framework and costing methods.

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[3] Since cost estimates for most modes are based on average automobile costs, the range of costs for other modes can usually be calculated from this estimate.

[4] James Strathman and Kenneth Dueker, "Understanding Trip Chaining," *1990 NPTS Special Reports on Trip and Vehicle Attributes DRAFT*, USDOT, (Washington DC), 1994.

"Do I need to read all of the technical stuff?"

Much of this analysis is specialized and tedious, and some sections assume a basic understanding of economic theory. It is simply a matter of document style that these chapters are not a separate technical appendix, and many readers may prefer to treat them as such. Most readers will want to review two or three chapters dealing with costs that they are familiar with in order to understand in general how the estimates are derived and how the costing chapters are organized. Few will need to study each cost chapter in detail.

3.0.1 Measuring Costs

It is important to determine whether a marginal or average analysis is appropriate for ridesharing and transit costs. *Marginal* analysis assumes that the vehicle will be making the same trip anyway, so each passenger only incurs additional costs in terms of increased vehicle weight, increased internal accident risk and additional stops. An *average* cost analysis assumes that the vehicle trip would not occur without the need created by the passengers, so each passenger bears an equal share of total cost.

Marginal costs tend to emphasize the short-term, while average costs tend to emphasize a longer term perspective. For example, the short term cost of accommodating more transit passengers with existing bus capacity is simply small increases in fuel consumption, air pollution, and boarding delay. If increased ridership requires more buses, more or longer routes, earlier replacement or upgrading of equipment, or other expenses, these are costs of the additional passengers. Car and van pooling costs seem most appropriately based on *marginal* costs, on the assumption that the vehicle driver will take the trip anyway, although trip length and travel time may increase with additional passengers. Van pool passengers must also bear a portion of the additional costs of a van rather than a smaller vehicle that the driver would normally choose in the absence of a van pool program.

Transit rider costs seem most appropriately based on *average* costs, since the system exists specifically for them; drivers would not drive and buses would not run without riders using the system. According to the American Public Transit Association, urban transit buses carry approximately their full seating capacity in the peak direction during peak hours, or about 53 passengers on a 40 foot bus, but carry fewer passengers during off-peak periods, on return trips, and toward the ends of the line.[5]

Average bus occupancy rates are used in this analysis even during peak periods when buses are full since low occupancy off-peak trips result from the need to provide capacity during peak period trips. Since the system's total number of buses, bus size and labor costs are generally determined by peak trip needs, it seems reasonable to charge passengers on the system's average costs rather than a simple marginal cost. Thus, although the cost per rider of operating a full, peak hour bus is lower than for a lightly loaded off-peak bus, from an overall system perspective the off-peak passenger incurs a lower marginal cost because of excess capacity. This conclusion is indicated by the increasing tendency of transit systems to offer off-peak rider discounts.

3.0.2 Modes Defined[6]

1. **Average Car.** A medium sized car or light truck that averages 21 mpg overall (16 mpg city driving, 24 mph highway driving). Overall average occupancy is 1.5, but for commuting (peak-period travel) is 1.1.

2. **Fuel Efficient Car.** A small four passenger car that averages 40 mpg overall (34 mpg city driving, 46 mpg highway driving). Overall average occupancy is the same as an average automobile.

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[5] Terry Bronson, American Public Transit Asso. Research Analyst. Conversation, April 14, 1994.
[6] Fuel efficiency based on *Highway Statistics 1990*, USDOT (Washington DC), 1991, Table VM-1. Occupancy values from Homburger, Kell and Perkins, *Fundamentals of Traffic Engineering, 13th Edition*, Institute of Transportation Studies, UCB (Berkeley), 1992, p. 11-8.

3. **Electric Car.** A small four passenger battery powered electric car based on current technology, which consumes an average of 0.5 kWh per mile of travel.

4. **Van.** (including driver) A survey of dealers indicates that 14 passenger vans get 13 to 15 mpg city driving, 18 to 21 mpg highway driving. Assuming that van pool driving is 2/3 highway and 1/3 city driving, and that actual peak period driving fuel efficiency is 15% lower than these ratings due to increased congestion and imperfect driving, overall average fuel efficiency is 15 mpg.

5. **Rideshare Passenger.** This is the incremental cost of a car pool, van pool or transit rider. A survey of dealers indicates that fuel efficiency decreases 2-3 mpg for a van loaded with 10 passengers (1,500 pounds) compared with no load. This indicates an average per passenger reduction in fuel efficiency of 0.25 mpg. This same value is used for automobile passengers. In addition, some passengers require additional driving to be picked up. Assuming that this averages 0.01 extra distance per rideshare passenger (2% extra miles to assemble a 2 person car pool, 10% extra miles to assemble a 10 passenger van), this means a 0.01 x 15 mpg = 0.15 mpg average fuel consumption premium in addition to the 0.25 reduction in fuel efficiency, giving a total average fuel cost of 0.4 mpg per rideshare passenger.

6. **Diesel Bus.** A 40 foot bus (total capacity 53 seated and 20 standing passenger) with an Urban Peak occupancy rate of 25 passengers, and an overall average occupancy of 9.3 passengers, averaging 6.5 mph.

7. **Electric bus/Trolley.** A 65 maximum passenger bus or trolley with a peak period occupancy of 30 passengers, an overall average occupancy of 14 passengers[7] that averages 6.5 mpg energy equivalent.

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[7] *1993 Transit Fact Book*, American Public Transit Association (Washington DC), p. 78 and 79 indicates 14.0 overall average passengers per trolley mile, and 24.5 overall average passengers per light rail mile.

8. **Motorcycle.** A medium size motorcycle that averages 45 mpg for urban driving and 55 mph for rural driving.

9. **Bicycle.** A moderate priced bicycle.

10. **Walk.** A relatively healthy person traveling an average of 10 blocks per trip.

11. **Telecommute.** This represents two commute trips displaced by allowing an employee to work from home.

3.0.3 Avoiding Double Counting

It is important to prevent double counting when calculating costs. This is occasionally difficult because some cost categories overlap. Every effort has been made to prevent this problem. Two areas require special clarification.

There is potential for overlap between energy (chapter 3.12), air pollution (chapter 3.10), water pollution (chapter 3.15), and waste disposal (chapter 3.16) costs. To avoid this problem, emissions occurring during production and distribution are considered air and water pollution costs, and are *not* included in the energy cost estimate. Pollution impacts that occur after use (such as crankcase oil emissions) are considered waste disposal costs.

There is also potential for overlap between equity & option value (chapter 3.9), the barrier effect (chapter 3.13), and land use impacts (chapter 3.14). To avoid double counting, the barrier effect includes only direct costs to pedestrians and cyclists of *vehicle traffic*; land use costs focus on problems created by *land use changes*; transport inequity includes the problems created for non-drivers by an automobile oriented *transportation system*.

3.1 Vehicle Costs

Definition: Vehicle ownership and operating costs.

Description: Automobile user costs include:

Fixed Costs	Variable Costs
• Vehicle purchase or lease	• Maintenance and repair
• Insurance	• Fuel, fuel taxes and oil
• Registration and vehicle taxes	• Paid parking and tolls

Discussion: The key factor in determining whether a cost is internal or external, fixed or variable, is how it is perceived by users and therefore how it influences purchase and consumption decisions. Some costs, such as liability insurance, may be partially variable since the price is affected at least somewhat by annual mileage, but are considered variable costs only if users typically consider them when make travel decisions. Research has found that automobile owners often underestimate vehicle operating costs and ignore variable costs such as maintenance.[1]

Motorcycle user expenses range from much lower to somewhat higher than an average automobile, and are significantly affected by insurance costs. Electric cars are currently relatively expensive to purchase (approximately 150% to 200% the price of a comparable gasoline automobile), and require replacement of battery packs every 20,000-30,000 miles at a price of $2,000-$3,000, for an average cost range of $0.07 to $0.15 per mile.[2] Other user expenses, including, tires, insurance, licensing, and parking are comparable to gasoline vehicles, and maintenance costs are slightly reduced. Typical small electric vehicles consume 0.25 to 0.5 kWh per mile, so energy costs average $0.1 to $0.06 per mile based on typical residential energy rates.

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[1] Cy Ulberg, *Psychological Aspects of Mode Choice*, WSDOT (Olympia), 1989, p. 20.

[2] Information from U.S. Department of Energy, *Electric and hybrid Vehicles Program*, USDOE, (Washington DC), 1993; Fuel Cell Lab staff at University of California at Davis, conversation 25 August 1994; Gil McCoy, Washington State Energy Office (Olympia.) conversation 16 August 1994.

Estimates:

- The American Automobile Manufacturer's Association estimates average user vehicle annual operating costs in 1993 were $4,514 ($0.45 per mile based on average mileage) for an intermediate size U.S. car.[3] Of this cost, $3,584 ($0.36 per mile) is fixed and $930 ($0.09 per mile) is variable (including gas and oil, maintenance and tires).

- Apogee Research estimates user costs for various modes in Boston, MA and Portland, ME, including averages of $0.076 per mile for bicycling and 7.1 for walking.[4]

- The Federal Highway Administration uses a different approach from the AAMA to calculate financing and depreciation, which results in a lower average value per mile.[5] Table 3.1-1 summarizes their estimates for vehicle types used in this report.

Table 3.1-1 **Cost of Owning and Operating Selected Motor Vehicles (1991 ¢/mile)**

	Deprec-iation	**Insur-ance**	**Maint-enance**	**Parking & Tolls**	**Tires**	**Finance Charges**	**Lic. & Reg.**	**Fuel & Oil**	**Fuel Taxes**	**Total**
Vehicle Size	Fixed	Fixed	Variable	Variable	Variable	Fixed	Fixed	Variable	Variable	
Sub-Compact *(E-E car)*	**8.6**	**7.1**	**4.0**	**1.3**	**0.7**	**1.6**	**0.8**	**3.5**	**1.3**	**28.9**
Intermediate *(Average Car)*	**10.7**	**7.0**	**4.2**	**1.3**	**1.0**	**2.0**	**0.9**	**4.6**	**1.7**	**33.4**
Full-size Van *(Van)*	**14.2**	**8.5**	**4.2**	**1.3**	**1.4**	**2.9**	**1.2**	**8.1**	**3.0**	**44.8**

- The Canadian Automobile Association estimates fixed automobile costs at $4,975 Canadian per year, and variable costs at $0.083 per kilometer, (US$0.10 per mile).[6]

- Kenneth Small estimates that vehicle operating costs on urban arterials average 40% higher per mile than driving on highways, and this cost increases proportional to travel time when congestion reduces traffic speed to 30 mph on an highway or 20 mph on an arterial.[7] He states that vehicle depreciation is only slightly affected by mileage.

- Electric car user costs are estimated based on a sub-compact's costs in Table 3.1-1, by increasing depreciation and finance by 75%, increasing maintenance by $0.09 per mile (for battery replacement), reducing fuel costs to $0.03, and eliminating fuel taxes.[8]

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[3] *Facts and Figures '93*, American Automobile Manufacturers Association (Washington DC), 1993.

[4] Apogee Research, *The Costs of Transport*, Conservation Law Foundation (Boston), 1994, p.83 and 92.

[5] Jack Faucett Associates, *The Costs of Owning and Operating Automobiles, Vans and Light Trucks, 1991*, FHWA (Washington DC), 1992.

[6] *1992-1993 Car Costs*, Canadian Automobile Association (Ottawa), brochure.

[7] Kenneth Small, *Urban Transportation Economics*, Harwood (Chur), 1992, p. 76.

[8] The exclusion of electric vehicle users from paying dedicated road taxes may eventually present a revenue shortfall problem when such vehicles begin to represent a significant portion of road use, which may eventually require some sort of tax on electric vehicle use.

Table 3.1-2 **Cost of Owning and Operating Small Electric Car (1991 ¢/mile)**

	Deprec-iation	Insur-ance	Maint-enance	Parking & Tolls	Tires	Finance Charges	Lic. & Reg.	Fuel & Oil	Fuel Taxes	Total
	Fixed	Fixed	Variable	Variable	Variable	Fixed	Fixed	Variable	Variable	
Electric Car	**15.1**	**7.1**	**13.0**	**1.3**	**0.7**	**2.8**	**0.8**	**3.0**	**0.0**	**43.8**

Variability: There is considerable variation in user costs depending on the vehicle and its use. An old but reliable, uninsured automobile may cost the user only a few hundred dollars a year, although in practice some of the depreciation savings from driving an older car are lost through higher repair costs. An expensive vehicle may incur an order of magnitude higher user costs, totaling many thousands of dollar each year, however, some of this cost may be considered to provide luxury or prestige, not transport.

Conclusions: Ownership and operating costs for average car, and vans are calculated using FHWA data. The FHWA data for an sub-compact car is modified to reflect greater fuel efficiency of the energy efficient car assumed in this study.[9] Electric vehicle costs are calculated as described above. Rideshare passengers incur no additional fixed cost and a 0.4 mpg reduction in fuel efficiency, as described in chapter 3.0. Transit fares average $1.00 per 8 mile trip, or $0.125 per mile, times 25 average passengers during peak periods and 9.3 average passengers at other times for buses, and 30 average passengers during peak periods and 9.3 aver passengers at other times for trolleys.[10]

Motorcycles costs are half of an energy efficient automobile, except for insurance which is doubled. Bicycling costs $0.07 per mile, most of which is fixed, and walking costs $0.04 per mile. Telecommuting is estimated to cost $0.20 per mile displaced, assuming an employee or employer spends $400 annually extra in equipment and utilities to

[9] The FHWA estimates that subcompacts consume 76% the fuel of an intermediate size car, equivalent to 28 and 21 mph respectively. In this study an energy-efficient car is assumed to average 40 mpg.
[10] *Transit Fact Book 1993*, American Public Transit Association (Washington DC), p. 13.

telecommute 100 days a year, at 20 commute miles per day displaced. Fixed costs are applied equally to all driving conditions; variable costs are assumed to represent Urban Off-Peak driving, and are increased 15% for Urban Peak travel and decreased by 15% for Rural travel.[11]

Best Guess **Fixed User Vehicle Ownership Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.206	0.206	0.206	0.206
Fuel Efficient Car	0.181	0.181	0.181	0.181
Electric Car	0.258	0.258	0.258	0.258
Van	0.268	0.268	0.268	0.268
Rideshare Passenger	0.00	0.00	0.00	0.00
Diesel Bus	0.00	0.00	0.00	0.00
Electric Bus/Trolley	0.00	0.00	0.00	0.00
Motorcycle	0.252	0.252	0.252	0.252
Bicycle	0.05	0.05	0.05	0.05
Walk	0.00	0.00	0.00	0.00
Telecommute	0.20	0.20	0.20	0.20

Best Guess **Variable User Vehicle Operating Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.147	0.128	0.109	0.124
Fuel Efficient Car	0.107	0.093	0.079	0.090
Electric Car	0.207	0.180	0.153	0.175
Van	0.207	0.180	0.153	0.175
Rideshare Passenger	0.003	0.003	0.002	0.002
Diesel Bus	3.125	1.160	1.160	1.553
Electric Bus/Trolley	3.75	1.160	1.160	1.678
Motorcycle	0.062	0.054	0.05	0.054
Bicycle	0.020	0.020	0.020	0.020
Walk	0.040	0.040	0.040	0.040
Telecommute	0.00	0.00	0.00	0.00

In addition to user costs, public transit vehicles receive operating subsidies. On average, 63.5% of transit operating expenses are subsidized from taxes.[12] Significant electric vehicle development costs are funded through government programs and through cross

[11] Based on fuel efficiency ratings which indicate that urban driving incurs about 30% higher fuel costs per mile than highway driving. These same ratios are assumed to apply to other variable costs.
[12] *Transit Fact Book 1993*, American Public Transit Association (Washington DC), p. 44.

subsidies within automobile companies that are required to sell a certain number of zero-emission vehicles to meet upcoming emission standards, but these subsidies will not be included in this estimate due to uncertainties.

Best Guess **Vehicle Operating Subsidies (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0	0	0	0
Fuel Efficient Car	0	0	0	0
Electric Car	0	0	0	0
Van	0	0	0	0
Rideshare Passenger	0	0	0	0
Diesel Bus	3.18	3.18	3.18	3.18
Electric Bus/Trolley	3.18	3.18	3.18	3.18
Motorcycle	0	0	0	0
Bicycle	0	0	0	0
Walk	0	0	0	0
Telecommute	0	0	0	0

Automobile Cost Range: The Minimum value is a rounded lower estimate and the Maximum is based on the AAMA estimate. Of course, the cost ranges for other types of automobiles, such as older, used cars and luxury vehicles are much greater.

	Minimum	Maximum
Fixed	$0.18	$0.36
Variable	$0.10	$0.15
Total	$0.28	$0.51

3.2 Travel Time Costs

Definition: The value of travel time.

Description: The value of travel time includes the cost to travelers of unpaid time, and the cost to employers for work time spent in travel. Although a small amount of recreational travel time has zero or negative costs (people would rather be traveling than engaged in other activities), the vast majority of travel time imposes a cost, either to the traveler during unpaid time, or to an employer for travel occurring during work time.[1] Travel time can also impose costs on perishable or urgently needed goods, and as capital costs of equipment, such as trucks. Travel time should be measured door-to-door, meaning that time spent parking and walking to and from a vehicle is considered part of the trip.

Discussion: Travel time is often determined to be the largest single cost of transport, and travel time savings the greatest potential benefit of transport facility improvements. Table 3.2-1 shows typical estimated benefits for UK. highway improvements:[2]

Table 3.2-1 **Typical Highway Improvement Benefits**

Benefit	Percent of All Benefits
Vehicle Operating Cost Savings	0%
Travel Time Savings-Work	51%
Travel Time Savings-Nonwork	29%
Accident Savings	20%
Total	100%

Travel time savings are the largest single benefit in most road improvement projects.

Because of this importance, the values of travel time and travel time savings have been widely studied and various estimates are recommended for use in economic analysis. The

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[1] Some people have suggested incorrectly that automobile travel time costs are reduced by amenities such as portable phones. Although these may reduce some discomfort and inefficiency, there is little indication that individuals would prefer to sit in a car (even with a telephone) than be at their destination. The high charges associated with portable telephone use (about $30/hr.) indicate a very high value of travel time.

[2] Ian Heggie and Simon Thomas, "Economic Considerations," *Transportation and Traffic Engineering Handbook, 2nd Edition*, Institute of Transportation Engineers/Prentice-Hall (Englewood), 1982, p.419.

earliest formal application of travel time savings in transport investment analysis was in 1960 of a proposed freeway through London, in which travel time savings represented 60% to 80% of total expected benefits.[3] A 1963 study of expanding London's subway system also incorporated travel time saving values.

Table 3.2-2 **Estimated Value of Travel Time Savings From Various Studies**[4]

Author and Year	Country	% of Avg. Wage	Trip Purpose	Mode
Beesley (1965)	UK	33-50	Commuting	Auto
Quarmby (1967)	UK	20-25	Commuting	Auto, Transit
Stopher (1968)	UK	21-32	Commuting	Auto, Transit
Oort (1969)	USA	33	Commuting	Auto
Thomas & Thompson (1970)	USA	86	Interurban	Auto
Lee & Dalvi (1971)	UK	30	Commuting	Bus
"	UK	40	Commuting	Auto
Wabe (1971)	UK	43	Commuting	Subway, Rail
Talvittie (1992)	USA	12-14	Commuting	Auto, Transit
Hensher & Hotchkiss (1974)	Australia	2.7	Commuting	Hydrofoil, Ferry
Kraft & Kraft (1974)	USA	38%	Interurban	Bus
McDonald (1975)	USA	45-78	Commuting	Auto, Transit
Ghosh et al. (1975)	UK	73	Interurban	Auto
Guttman (1975	USA	63	Leisure	Auto
"	USA	145	Commuting	Auto
Hensher (1977)	Australia	39	Commuting	Auto
"	Australia	35	Leisure	Auto
Nelson (1977)	USA	33	Commuting	Auto
Hauer & Greenough (1982)	Canada	67-101	Commuting	Subway
Edmonds (1983)	Japan	42-49	Commuting	Auto, Bus, Rail
Deacon & Sonstelie (1985)	USA	52-254	Leisure	Auto
Hensher & Truong (1985)	Australia	105	Commuting	Auto, Transit
Guttman & Menashe (1986)	Israel	59	Commuting	Auto, Bus
Fowkes 91986)	UK	27-59	Commuting	Rail, Coach
Hau (1986)	USA	46	Commuting	Auto, Bus
Chui & McFarland (1987)	USA	82	Interurban	Auto
Mohring et al. (1987)	Singapore	60-120	Commuting	Bus
Cole Sherman (1990)	Canada	93-170	Commuting	Auto
"	Canada	116-165	Leisure	Auto

Numerous studies have been performed to estimate the value of travel time savings.

[3] Dr. W. Waters, *Value of Time Savings for Economic Evaluation of Highway Investments in British Columbia*, B.C. Ministry of Transportation and Highways (Victoria), 1992, p.4.

[4] Dr. W. Waters, *Value of Time Savings for Economic Evaluation of Highway Investments in British Columbia*, B.C. Ministry of Transportation and Highways, (Victoria), 1992, p.42.

Table 3.2-2 summarizes travel time values relative to wage rates from different studies. Various time value schedules have been developed based on such studies. The American Association of State Highway and Transportation Officials (AASHTO) has published such a schedule, as have several European national transport agencies. Many road agencies use the AASHTO values or similar schedules.[5] Most of these schedules include higher rates for commercial travel, some by class of vehicle. Some have slightly higher time values for commuting compared with other personal travel. Some schedules have different rates depending on road conditions. Drivers' time is often valued at a higher rate than passengers', due to their higher stress, and higher time values are sometimes used for bus passengers who must stand on the bus or while waiting at a bus stop.[6]

There is some indication that time values are non-linear; time spent on commutes that are less than about 20 minutes seem to incur lower costs in terms of driver stress than time spent on longer commutes, but this has not been quantified.[7] A recent study indicates that unexpected delays impose much higher costs than predictable delays.[8] Cy Ulberg emphasizes that the value of time should be calculated based on *perceived time*, which is not always the same as chronological time.[9] Walking and bicycling seem to incur relatively low time costs under favorable conditions, indicated by their popularity as recreation activities and the willingness of some commuters to walk or ride despite longer travel

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[5] Dr. W. Waters, *Value of Time Savings for Economic Evaluation of Highway Investments in British Columbia*, B.C. Ministry of Transportation and Highways (Victoria), 1992, p.4, 92.

[6] For example, The Netherlands uses separate time values for "Commuting," "Business" and "Other." The United Kingdom's Cost Benefit Analysis guidebook states that in-vehicle time should be doubled for walking to and waiting for a bus. New Zealand uses 25% of wage rate for bus rider, but 40% while walking to the bus stop and 50% for waiting at a bus stop. As cited in Waters, 1992.

[7] Raymond Novaco, *Commuting Stress, Ridesharing, and Gender; Analysis From the 1993 State of the Commute Study in Southern California*, Transportation Research Board General Meeting, January 1994; Kenneth Small, *Urban Transportation Economics*, Harwood (Chur), 1992, p. 46.

[8] Robert Noland and Kenneth Small, *Travel Time Uncertainty, Departure Time Choice, and the Cost of the Morning Commute*, TRB Annual Meeting (Washington DC), Paper 950206, January 1995.

[9] Cy Ulberg, *Psychological Aspects of Mode Choice*, WSDOT (Olympia), 1989, p. 17.

times, and relatively high travel time costs under poor conditions.[10] Kenneth Small cites research by Bruzelius indicating that walking and waiting time costs are double typical travel time costs, but acknowledged considerable variation among studies.[11]

These factors have implications for valuing modal shifts. Although riding a bus, car pooling, bicycling, or walking often take more travel time, under favorable conditions this additional time is charged at a lower rate than driving alone because bus and car pool passengers can relax or perform productive work, and bicyclists and walkers benefit from exercise. However, bicycling, walking, or riding a bus incur higher time costs when conditions are unpleasant, for example, if bus riders must wait in uncomfortable conditions or stand in a crowded bus. Even at the lower price ranges, the value of vehicle occupants' time significantly exceeds variable vehicle operating costs for most travel. For example, an automobile averaging 30 mph incurs marginal vehicle operating costs of about $0.10 per mile, but time costs of $0.25 per mile if travel time is valued at $7.50 per hour, and this cost increases substantially as congestion increases or if the car carries passengers. Average travel times, distances and speeds vary between modes, as shown in Table 3.2-3.

Table 3.2-3 **Commute Trip Time, Length and Speed by Mode**[12]

	Automobile	**Transit**	**Walking**	**All**
Commute Travel Time (min.)	19.0	49.9	9.6	19.7
Commute Trip Length (miles)	11.0	12.6	0.5	10.7
Commute Average Speed (mph)	34.7	15.2	3.1	32.3

Average travel time, distance and speed vary by mode.

[10] Todd Litman, *Bicycling and Transportation Demand Management*. Paper presented at the Transportation Research Board General Meeting, January 1994.
[11] Kenneth Small, *Urban Transportation Economics*, Harwood (Chur), 1992, p. 45.
[12] Alan Pisarski, *Travel Behavior Issues in the 90's*, USDOT (Washington DC), July 1992, p. 70.

Estimates:

- The AASHTO manual values average travel time savings at $10.44 per vehicle hour in 1985 dollars, which represents a mix of private and commercial vehicles.

- Apogee Research developed estimates of travel time costs per passenger mile for several modes under urban peak and urban off-peak travel at high, medium and low densities in Boston, MA and Portland, ME, based on average travel times.[13] Time values were based on 50% of average local wages for commuting and 25% for other personal travel.

Table 3.2-4 **Travel Time Costs in Two Cities (¢ per passenger mile)**

	Express-way		Non-Expwy		Comm. Rail		Rail Transit		Bus		Bicycle		Walk	
Boston	Peak	Off-P	Peak	Off-P	Peak	Off-P	Peak	Off-P	Peak	Off-P	Peak	Off-P	Peak	Off-P
High	24.3	9.6	40.4	23.9	28.9	22.7	40.1	28.6	50.5	39.8	60.6	47.8	243	159
Medium	15.2	8.0	24.3	15.9	19.8	14.0	28.1	25.3	50.5	39.8	60.6	47.8	202	159
Low	11.0	8.0	20.2	13.6	19.0	13.3	n/a	n/a	50.5	39.8	60.6	47.8	202	159
Portland														
High	11.1	7.8	19.9	13.1	n/a	n/a	n/a	n/a	42.6	33.5	49.8	39.2	166	131
Medium	10.0	7.1	16.6	11.2	n/a	n/a	n/a	n/a	42.6	33.5	49.8	39.2	166	131
Low	7.7	6.0	12.4	9.8	n/a	n/a	n/a	n/a	30.2	23.8	49.8	39.2	166	131

- The California Energy Commission calculated the value of congestion delay reductions at $10.60 in their Personal Vehicle Model.[14]

- Travel time savings values developed by Professor W. Waters are shown below. Average wage rates are currently about $15/hr Canadian (U.S. $11.)

Table 3.2-5 **Travel Time Saving Values for British Columbia Ministry of Transportation and Highways Road Improvement Analysis**[15]

	<u>Travel Time Values</u>
Commercial Vehicle Driver	Wage rate plus fringe benefits
Personal Vehicle Driver	50% of current average wage
Adult Car or Bus Passenger	35% of current average wage
Child passenger under 16 years	25% of current average wage

Congestion increases travel time costs for drivers by the following amounts:

<u>Level of Service (LOS)</u>

D: multiply by 1.33 E: multiply by 1.67 F: multiply by 2.0

This travel time schedule includes higher rates for drivers under congested conditions.

[13] *The Costs of Transportation: Final Report*, Conservation Law Foundation (Boston), 1994, p. 119-120.
[14] California Energy Commission, *1993-1994 California Transportation Energy Analysis Report Technical Appendices*, California Energy Commission (Sacramento), Feb. 1994, 3C.
[15] *The Value of Time Savings for The Economic Evaluation of Highway Investments in British Columbia*, Dr. W. Waters, British Columbia Ministry of Transportation and Highways (Victoria, B.C.), March 1992.

Variability: User travel time values vary considerably depending on who is traveling, for what purpose and under what conditions.

Conclusions: The British Columbia value of travel time schedule is used as a basis for costing because it is current and comprehensive, for an automobile driver time value of US$6.00 (50% of $12.00 average wage) and passenger travel time value of US$4.20 (35% of $12.00). These values are used for average automobile, fuel efficient cars, electric cars, vans and motorcycles. Urban Peak driving speeds are estimated to average 30 mph,[16] and incur a congestion premium of 16.5%, assuming that half the trip experiences LOS D congestion. Urban Off-Peak and Rural travel costs are based on average speeds of 35 and 40 mph respectively, and no congestion premium.

Rideshare, bus, and trolley trips typically take longer than driving alone,[17] although on congested routes with HOV facilities these modes can actually be faster. Rideshare passengers such as car and van poolers are assumed to incur 20% additional travel time in order to collect riders. Buses and trolleys are estimated to incur 40% additional travel time, including waiting and slower average travel speeds due to stops. A travel time rate of $4.20 per hour is used for vehicle passengers, and no congestion premium is charged. Unpleasant conditions, such as overcrowded buses would significantly increase this cost. Walking and bicycling travel time is charged at $3.00 per hour, which is half of the standard rate for SOV drivers, due to enjoyment, health and moral satisfaction benefits, although this costs is sensitive to sidewalk and road conditions, and personal preference. Walking is assumed to average 3 mph. Bicycling is assumed to average 10 mph, and incurs the 16.5% premium for Urban Peak travel. Telecommuting incurs no time cost.

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[16] This speed is roughly calculated based on the 1990 National Public Transportation Survey results showing that average commute time is 19.7 minutes and distance is 10.6 miles, averaging 32.4 mph.
[17] Especially since these trips are defined to include walking and waiting at the stop.

Best Guess **User Travel Time Costs (Dollars per Passenger Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.23	0.17	0.15	0.174
Fuel Efficient Car	0.23	0.17	0.15	0.174
Electric Car	0.23	0.17	0.15	0.174
Van	0.23	0.17	0.15	0.174
Rideshare Passenger	0.18	0.154	0.135	0.152
Diesel Bus	0.225	0.193	0.169	0.190
Electric Bus/Trolley	0.225	0.193	0.169	0.190
Motorcycle	0.23	0.17	0.15	0.174
Bicycle	0.35	0.30	0.30	0.31
Walk	1.00	1.00	1.00	1.00
Telecommute	0.00	0.00	0.00	0.00

Automobile Cost Range: Studies in Table 3.2-2 are used for minimum and maximum.

Minimum	Maximum
$0.11	$0.34

3.3 Accident Costs

Definition: Automobile accident costs net insurance disbursements.[1]

Description: Automobile accident costs include deaths, injuries, pain, disabilities, lost productivity, grief, material damage, and accident prevention.

Discussion: Every year about 50,000 Americans die, about 3.4 million are injured, and millions more experience financial losses from automobile accidents.[2] Although the accident rate per VMT and the fatality rate per accident have decreased over the years, increased mileage has kept pace so the number of deaths has stayed relatively constant.

Although nobody considers human life a commodity, many individual and social decisions are made that trade risk of injury and death against market goods. Recent research estimates appropriate monetary values for risk and risk reduction by tracking such tradeoffs.[3] There are two general approaches to monetizing these costs.[4] The *Human Capital* method measures only market costs, including property damage, emergency services, medical treatment, lost productivity, and accident prevention expenditures. This typically places the value of saving a human life at approximately $500,000, with lesser values for various injuries. The *Comprehensive* approach adds non-market costs, including pain, grief, and reduced quality of life, as reflected in people's willingness-to-pay to avoid such injuries. This approach typically places the value of preventing a human death at $2,000,000 to $5,000,000, with related values for injuries.

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[1] Insurance disbursements are deducted from the cost defined here prevent double counting insurance payments included in chapter 3.1. Other accounting models could handle this overlap differently.
[2] *Traffic Safety Facts, 1992*, National Highway Traffic Safety Admin. (Washington DC), 1993, p. 86.
[3] Frank Haight, "Problems in Estimating Comparative Costs of Safety and Mobility," *Journal of Transport Economics and Policy*, January 1994, p. 14-17, gives an excellent summary of this field.
[4] Ted Miller, *The Costs of Highway Crashes*, FHWA (Washington DC), publ. No. FHWA-RD-055, 1991

Accident Cost Distribution

An important and challenging problem is to determine what portion of accident costs are external and which are internal. The existence of external accident costs can be determined by asking, "*Should society care if automobile accidents occur, given current compensation?*" Empirical evidence indicates that society makes a significant effort to reduce automobile accidents, so external costs appear to exist. Even an accident that only injures the driver who caused it imposes external costs in terms of emergency and medical expenses, lost productivity, and grief to family and friends.

Accident costs imposed directly on the vehicle user are considered internal. Accident costs imposed on non-users are internalized to the degree that they are compensated by users, either directly or through insurance. Many accident costs (especially non-market costs such as pain and suffering) are not fully compensated, leaving residual external costs. Even people who never use an automobile may be forced to pay these costs. Liability insurance pools accident costs among all insured drivers, so accident costs that are compensated by insurance disbursements are external at the level of individual drivers but internal at the sectorial level (all drivers).[5] About half of the market costs of roadway accidents are covered by insurance disbursements, averaging $0.032 per vehicle mile (50% of $137 billion divided by 2,147 billion miles traveled).[6]

Accident analysis usually assigns accident cost to the heavier vehicle, no matter who is legally responsible for an accident. For example, if an automobile injures a pedestrian, the responsibility is allocated to the automobile since it is the heavier vehicle. Costs of crash between a train and an automobile are assigned to the train. Table 3.3-1 summarizes accident cost categories and how they are allocated.

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[5] As discussed in section 1.4, which standard to use in a particular analysis depends on whether the concern is equity or efficiency.

[6] Ted Miller, *The Costs of Highway Crashes*, FHWA (Washington), 1991, Figure 38.

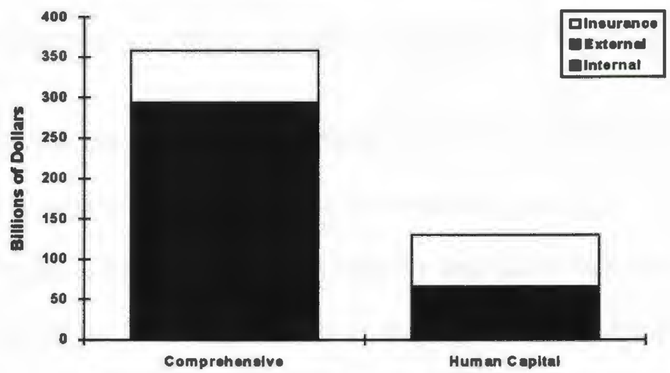
Table 3.3-1 **Allocation of Accident Costs**

Allocation	Market	Non-Market
Internal	Vehicle damage deductible.	Uncompensated injuries.
Insurance	Damages and lost income compensation.	Pain and grief compensation.
External	Uncompensated damages and lost income.	Uncompensated pain and grief.

Some accident costs can be considered internal, some external, and some internalized among all drivers who pay for insurance (internal at the sector level).

Ted Miller estimates that accident costs are divided as shown in Figure 3.3-1

Figure 3.3-1 **Accident Cost Distribution**[7]



This graph compares accident cost allocation based on two estimates of total accident costs. The Comprehensive estimate includes pain, grief and reduced quality of life costs.

As an example of the use of this analysis, consider the accident cost implications of a program that allows people who currently drive to use a safer form of transportation, thereby reducing automobile accidents.[8] Individual drivers would benefit from a reduction in their own (internal) accident risk. The reduction in insurance disbursements would benefit insurance companies in the short run, but in a competitive market savings would eventually be passed on to drivers through lower insurance charges. The reduction in

[7] Ted Miller, personal communication, July 30, 1994, based on cost estimates in his *Cost of Highway Crashes* study published by the Urban Institute. This is considered a conservative estimate because a relatively low value of human life was used.

[8] In addition to the direct reduction in accidents, reducing traffic volumes on roadways can also significantly reduce the accident rate per VMT, according to Forkenbrock, et al., *Safety and Highway Investment*, Midwest Transportation Center (Iowa City), 1994, p. 35.

external accident costs would also benefit society in general through reduced medical and disability costs that are not compensated by insurance premiums.

Peter Miller and John Moffet develop an accident cost allocation model based on marginal risk. Their results imply that accident costs are divided about equally between internal and external components.[9] Transport Concepts cities estimates that 3% to 47% of accident costs are external, and argue that the higher range is most appropriate when all costs are considered, especially if users have no safer travel alternative.[10] They therefore treat all non-market costs of accidents between freight vehicles and other road users as external.

Kenneth Small considers the additional accident risk resulting from additional vehicles in the traffic stream (he estimates that accidents rise with the square of traffic flow based on the number of two-vehicle interactions), and the fact that many accident costs are not borne by the user to estimate that about 50% of accident costs are external.[11]

Jan Jansson developed a model of marginal external accident costs which emphasizes the risk imposed by motor vehicles on "unprotected road users" (pedestrians and bicyclists), and direct costs to society, such as emergency services and medical expenses.[12] He states that about two-thirds of automobile accident fatalities and half of all injuries in European cities are unprotected road uses, which is higher than in North American cities. He also discusses, but does not resolve, the question of whether accident risk between automobiles imposes external costs.

Robert Davis also emphasizes the difference between external (*transitive*) and internal (*intransitive*) accident risk.[13] He explores the equity and ethical implications of accident

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[9] *The Price of Mobility*, National Resource Defense Council (Washington DC), Oct. 1993, p. 30.
[10] *External Costs of Truck and Train*, Transport Concepts (Ottawa), October 1994, p. 12.
[11] Kenneth Small, *Urban Transportation Economics*, Harwood (Chur), 1992, p. 80.
[12] Jan Jansson, "Accident Externality Charges," *Journal of Transport Economics and Policy*, January 1994, p. 31-42.
[13] Robert Davis, *Death on the Streets*, Leading Edge (North Yorkshire), 1992, p. 23.

risk imposed by automobile drivers on "vulnerable" road users such as pedestrians and cyclists. Davis argues that the true costs of accidents is understated by official analysis, both because many pedestrian and bicycle accidents are not captured in police statistics, and because a major portion of this cost is the loss of mobility and security to non-drivers.

Bicycle and Pedestrian Accident Risk

Studies indicate that walking and bicycling incur higher injury per mile than driving, although the exact value is difficult to determine with because total pedestrian and bicycle mileage is not measured, and because many such injuries are unreported.[14] Many of these accidents result from rider careless; the accident risk for a responsible (trained, sober, and wearing a helmet) adult bicyclist is significantly lower.[15] Since bicyclists tend to travel shorter distances than drivers,[16] the relative accident risk *per trip* is lower than *per mile*.

If accident risk is defined in terms of total *health risk*, the aerobic benefits of walking and bicycling compensate for accidents.[17] One estimate concludes that the aerobic exercise of bicycling outweigh accident risk by 20 to 1 in average life expectancy.[18]

Estimates:

- Apogee Research estimated accident costs in Boston, MA and Portland, ME for several modes. Costs were allocated to users, government and society. Totals are shown in Table 3.3-2.

Table 3.3-2 **Total Accident Costs in Two Cities (¢ per passenger mile)[19]**

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[14] Charles Komanoff and Cora Roelofs, *The Environmental Benefits of Bicycling and Walking*, FHWA National Bicycling and Walking Study Case Study #15 (Washingon DC), January 1993.
[15] Todd Litman, *Bicycling and TDM*, Transportation Research Board General Meeting, Jan. 1994.
[16] For example, drivers frequrently travel several miles to regional shopping centers while pedestrians and bicyclists use local shops and services.
[17] *Benefits of Bicycling and Walking to Health*, National Bicycling and Walking Study #14, USDOT, FHWA (Washington DC), 1992.
[18] Dr. Mayer Hillman, "Reconciling Transport and Environmental Policy," *Public Administration*, Vol. 70, Summer 1992, pp. 225-234.
[19] Apogee Research, *The Costs of Transportation: Final Report,* Conservation Law Foundation (Boston), 1994, p. 112-118.

Boston	Express-way	Non-Expwy	Comm. Rail	Rail Transit	Bus	Bicycle	Walk
High	1.2	6.3	2.6	1.9	1.8	3.2	1.4
Medium	1.2	6.3	2.6	1.9	1.8	3.2	1.4
Low	1.2	6.3	2.6	n/a	1.8	3.2	1.4
Portland							
High	2.0	5.0	n/a	n/a	11.6	3.2	1.4
Medium	2.0	5.0	n/a	n/a	11.6	3.2	1.4
Low	2.0	5.0	n/a	n/a	3.7	3.2	1.4

- The Californian Energy Commission estimates automobile accident costs at $0.118 per VMT, and bus accident costs at $0.26 per VMT ($0.014 per passenger mile based on 18.5 average passengers). Of the bus accident costs, 22% is estimated to be internal.[20] (This may somewhat overstate true bus accident risk, since transit systems are reported to be vulnerable to false but successful liability claims.)

- Chirinko and Harper find that automobile safety features (seat belts, air bags, etc.) encourage risky behavior which offsets much of the safety gain and significantly increases pedestrian and bicycle accidents.[21] They predict that over 1/3 of the 33% potential fatality reductions due to mandated air bags would be offset by increased driver risk, and pedestrian and bicycle fatalities would increase by 2%.

- Jan Jansson calculates the marginal external cost of driving to unprotected road users (pedestrians, bicyclists, and motorcyclists) with three risk levels and three estimates of the marginal increase of accident risk to these modes with respect to increased motor vehicle travel, as shown in Table 3.3-3.

Table 3.3-3 **Accident Costs to Unprotected Road Users by Jan Jansson ($/km)**[22]

	Unprotected Road User Accidents Per 100M Motor Vehicle Km		
Accident/VMT Ratio	10	20	30
1/3	$0.02	$0.04	$0.06
2/3	$0.04	$0.08	$0.12
1/1	$0.06	$0.12	$0.18

This table shows the costs of unprotected road user accidents from automobiles with three accident rates, and three ratios of accident rate to motor vehicle travel volumes.

- Per Kågeson estimates that European fuel taxes would need to increase an average of 0.23 ECU per litre (about $0.05 per mile) to internalize all accident costs.[23]

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[20] *1993-1994 California Transportation Energy Analysis Report, Technical Appendices*, California Energy Commission (Sacramento), Feb. 1994, p. 3D-7.
[21] Robert Chirinko and Edward Harper, Jr., "Buckle Up or Slow Down? New Estimates of Offsetting Behavior and their Implications for Automobile Safety Regulation," *Journal of Policy Analysis and Management*, Vol. 12, No. 2, 1993, pp. 270-296.
[22] Jan Jansson, "Accident Externality Charges," *Journal of Transport Eco. and Policy*, Jan. 1994, p. 40. The overall U.S. pedestrian fatality rate per 100M Motor Vehicle Km is approximately 0.15, but is higher in cities, based on NHTSA, *Traffic Safety Facts, 1992.*

- Brian Ketcham estimates traffic accident costs at $0.043 per vehicle mile, citing the Urban Institute's estimate.[24]

- Mac Elliott estimates the overall average fatality risk for bicyclists to be 4 to 4.5 times higher per mile than automobile occupants, but many of these accidents involve children or careless bicyclists.[25]

- Dr. Mayer Hillman estimates that the fatality rate for walking is 18 times higher than for car travel.[26]

- Ted Miller estimates the total value of 14.8 million motor vehicle accidents in 1988 at $358 billion (1988 dollars), a major component of which is pain, suffering, and lost quality of life.[27] An approximately $2 million value of human life is used, which is considered low. Table 3.3-4 shows his estimates of total accident costs.

Table 3.3-4 **FHWA Report Total Accident Cost Estimates by Mode**

Vehicle Type	1994 $ / VMT
Automobile/Van	0.14
Motorcycle	2.57
Bus	0.29
Light Truck	0.19
Med/Hvy Truck	0.13
Combination Truck	0.23

- Miller recently provided updated vehicle accident cost estimates shown in Table 3.3-5.

Table 3.3-5 **Miller's Estimate of Accident Costs**[28]

Mode	$ Per Vehicle Mile
Bus	$0.32
Commercial Air	$0.28
Car	$0.12
Car, Drunk Driver	$5.50
Car, Sober Driver	$0.06
Motorcycle	$1.50

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[23] Per Kågeson, *Getting the Prices Right*, European Fed. for Transport & Env., (Bruxelles), 1993, p. 130.
[24] Brian Ketcham, *Making Transportation Choices Based on Real Costs*, Konheim & Ketcham Inc. (New York), Oct. 1991, p. 10
[25] Mac Elliot, chair of the Human Powered Transport Subcommittee of the American Society of Civil Engineers, Committee correspondence, June, 1993.
[26] Dr. Mayer Hillman, *Cycling: Toward Health and Safety*, British Medical Association/Oxford Press (New York), 1992.
[27] Ted Miller, *The Costs of Highway Crashes*, FHWA (Washington DC), pub. No. FHWA-RD-055, 1991.
[28] Presented at FHWA Colloquium on Social Costs of Transportation, 12 Dec. 1994, Washington DC. Also see Miller, et al., "Railroad Injury: Causes, Costs, and Comparisons with Other Transport Modes," *Journal of Safety Research*, Vo. 25, No. 4, 1994, pp. 183-195.

- Peter Miller and John Moffet estimate annual external auto accident costs at $0.043 per urban mile and $0.03 per rural mile, and $0.007 per passenger mile for buses.[29]

- A 1992 USDOT National Highway Traffic Safety Administration study places 1990 accident costs at $137.5 billion (averaging about $0.065 per vehicle mile) because pain, suffering, and loss of quality of life were not included.[30]

- A National Research Council study concludes that small car occupants have a greater fatality risk than large car occupants in some types of accidents, but this difference has decreased due to improved designs and safety equipment and is partly compensated by reduced accident risk to other road users.[31]

- Rene Neuenschwander and Felix Walter estimate external accident costs in Switzerland to average 0.024 ECU per passenger kilometer (about $0.03 per mile).[32]

- The Office of Technology Assessment study places annual external market accident costs to individuals at $33 to $35 billion, plus about $4 billion per year in government costs.[33] Pain, suffering and lost quality of life inflicted on others (non-market external costs) are estimated to be worth $132 to $139 billion per year, for a total external accident cost average of $0.076 per vehicle mile.

- Émile Quinet summarizes accident costs by mode as shown in Table 3.3-6.[34] Based on this analysis he concludes that accident costs per passenger mile is about 10 times higher for cars than for buses, and that cars accident costs in passenger miles is virtually the same as accident costs for trucks in tonne miles.

Table 3.3-6 **Accident Costs by Travel Mode (U.S. dollars)**

Study	Location	Passengers (passenger-km)			Freight (tonne-km)		
		Car	**Bus**	**Rail**	**Road**	**Rail**	**Water**
Planco, 1990	FRG	.020	.004	0.003	0.012	0.008	0.000
Tefra, 1985	France				0.007	0.00	
Tefra, 1985	Belgium				0.003		
EcoPlan, 1991	Switzerland	0.030	0.007	0.004	0.070	0.001	
Hansson, 1987	Sweden, Urban	0.050	0.013	0.001	0.013	0.000	
Hansson, 1987	Sweden, Rural	0.088	0.001				

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[29] Peter Miller and John Moffet, *The Price of Mobility*, NRDC, Oct. 1993, p. 32.
[30] *Economic Cost of Motor Vehicle Crashes 1990*, National Highway Traffic Safety Admin., 1992.
[31] *Automotive Fuel Economy: How Far Should We Go*, National Academy Press (Washington DC), 1992.
[32] Felix Walter, *Social Costs of Swiss Transport Accidents*, ECOPLAN (Bern, Switzerland), p. 2.
[33] *Saving Energy in U.S. Transportation*, U.S. Office of Technology Assessment, 1994, p. 106 - 108.
[34] Émile Quinet, "The Social Costs of Transport: Evaluation and Links With Internalisatiion Policies," in *Internalising the Social Costs of Transport*, OECD (Paris), 1994, p.38.

- Kenneth Small estimates that total accident costs average $0.179 per mile, $0.09 of which are external costs. He estimates that external accident costs are 35% higher for trucks and 175% higher for buses.[35]

- Daniel Shefer concludes that traffic fatality risk declines with increased congestion due to reduced speeds, although he provides no specific function of this relationship.[36]

- D. Teufel estimates the following accident costs for different modes:

Table 3.3-7 **Hours of Lost Human Life per 1,000 Passenger Kilometers**[37]

Mode	Car	Bus	Rail	Bicycle	Pedestrian	Air
	11.5	1	0.4	0.2	0.01	1.4

- Transport Concepts cites European estimates that road travel is 8 times more dangerous for fatalities and 100 times more dangerous for injuries than rail.[38] They estimate truck accident risk to be six times greater than for train per unit of fright travel. A significant portion of rail fatalities result from accidents with motor vehicles at crossings, so cost estimates are sensitive to how the responsibility for these accidents is allocated. Based on various assumptions this study estimates freight accident costs at approximately $0.50 per ton mile for truck and $0.076 per ton mile for rail ($0.40 and $0.06 Canadian per tonne kilometer respectively).

Variability: Accident rates vary significantly with driver behavior and vehicle type. Although accident rates are higher in urban areas due to increased vehicle interactions, high-speed rural accidents are more dangerous. The FHWA study figures indicate that urban and rural accident costs per mile are approximately equal. David Greene and K.G. Duleep conclude that the additional injury and death risk from smaller, fuel efficient cars is relatively minor, especially when reduced risk to other road users are considered.[39]

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[35] Kenneth Small, *Urban Transportation Economics*, Harwood (Chur), 1992, p. 80-81.
[36] Daniel Shefer, "Congestion, Air Pollution, and Road Fatalities in Urban Areas," *Accident Analysis and Prevention*, Vol. 26, No. 4, 1994, pp. 501-509.
[37] D. Teufel, Die Zuykunft des Autoverkehrs (The Future of Motorized Transport), Umwelt- und Prognose Institut, Heidelberg, 1989, in *Transportation, The Environment and Sustainable Development*, p. 184.
[38] *External Costs of Truck and Train*, Transport Concepts (Ottawa), October 1994.
[39] David Greene and K.G. Duleep, "Costs and Benefits of Automotive Fuel Economy Improvement", *Transportation Research A*, Vol. 27A, No. 3, p. 221.

Conclusions: Accidents impose significant costs on individual road users and society. The Urban Institute/FHWA cost estimates are used as a starting point for calculating costs per vehicle mile because they are considered accurate and comprehensive. To avoid double counting insurance payments covered in Chapter 3.1, insurance disbursements are first subtracted from these estimates. Separate estimates are made for internal and external costs, based on Ted Miller's additional calculations. Internal accident costs are assigned per vehicle occupant, while external accident costs are assigned per vehicle. This is necessary because internal accident risk is relative to VMT and vehicle occupancy, while external risk is proportional simply to VMT. For example, a vehicle carrying only the driver is considered to impose only 10% of the *internal* accident risk as a vehicle carrying ten people, but the *external* accident risk is considered the same for both. Although rural driving has fewer accidents per mile, they tend to be more severe due to higher speeds, so rural and urban driving accident costs are considered equal.

Internal Accident Costs: Internal accident costs for average automobile and van occupants, including rideshare passengers, are estimated at $0.05 per passenger mile, calculated as the FHWA's average accident cost estimate of $0.14/VMT, times 75% internal costs, minus insurance disbursements of $0.031, divided by 1.5 average passengers.[40] Fuel efficient and electric cars are estimated here to impose 10% higher internal accident costs than an average car due to their smaller size. The California Energy Commission's accident cost estimate of $0.014 per passenger mile is used for buses and trolleys, 22% of which is internal, for a cost of $0.003 per PMT.

Motorcycle accident costs estimated at $1.50 to $2.57 per mile reflect this mode's high accident and injury rates. This extremely high value results in part because motorcyclists tend to be risk taking young men who have an accident rate 3 times higher than average

[40] Alan Pisarski, *Travel Behavior Issues in the 90's*, FHWA, (Washington DC), 1992, p. 52.

when driving any type of vehicle, so a lower cost estimate can be used to represent the accident costs normalized for the average rider.[41] Also, the motorcycle fatality rate per VMT has declined since the FHWA study was produced. For these reasons, a demographically average driver who currently rides a motorcycle is assumed here to have an accident cost 1/5th of the FHWA's study's estimate (about 1/3 of Ted Miller's more recent estimate), equal to $0.514. Even with this modification accident risk dominates motorcycle costs. Internal motorcycle accident costs are estimated to represent 85% of this cost (a higher ratio of internal costs since motorcycles are less likely to injure other road users) minus $0.07 for insurance disbursements (twice that of cars) resulting in $0.437 per mile. Bicycles and walkers are estimated to incur internal accident risk equal to that of automobile occupants. Telecommuting is not considered to incur any accident risk.

Best Guess **Internal Accident Costs (Dollars per Passenger Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.05	0.05	0.05	0.05
Fuel Efficient Car	0.055	0.055	0.055	0.055
Electric Car	0.055	0.055	0.055	0.055
Van	0.05	0.05	0.05	0.05
Rideshare Passenger	0.05	0.05	0.05	0.05
Diesel Bus	0.003	0.003	0.003	0.003
Electric Bus/Trolley	0.003	0.003	0.003	0.003
Motorcycle	0.437	0.437	0.437	0.437
Bicycle	0.05	0.05	0.05	0.05
Walk	0.05	0.05	0.05	0.05
Telecommute	0.00	0.00	0.00	0.00

External Accident Risk: Based on the FHWA report, the average external cost of driving average cars and vans is estimated by taking the 25% external portion of $0.14 per vehicle mile, for an average of $0.035 per mile. Note this is per *vehicle* rather than per *passenger*. Small, fuel efficient and electric cars incur a slightly lower external risk, estimated here at 5% less than a standard car. Rideshare passengers incur no additional external cost. The

[41] *Traffic Safety Facts 1992*, National Highway Traffic Safety Administration (Washington DC), 1993.

California Energy Commission accident cost estimate that external bus accident costs represent 78% of $0.26 per VMT is used for buses and trolleys. Motorcycles are estimated to have external accident costs of $0.077 per mile, representing 15% of $0.514. Since the costs of accidents between vehicles and pedestrians or bicycles is normally allocated to the motor vehicle, pedestrians and bicycles are estimated here to impose only 5% the external accident cost of average automobiles.

Best Guess **External Accident Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.035	0.035	0.035	0.035
Fuel Efficient Car	0.033	0.033	0.033	0.033
Electric Car	0.033	0.033	0.033	0.033
Van	0.035	0.035	0.035	0.035
Rideshare Passenger	0.00	0.00	0.00	0.00
Diesel Bus	0.20	0.20	0.20	0.20
Electric Bus/Trolley	0.20	0.20	0.20	0.20
Motorcycle	0.077	0.077	0.077	0.077
Bicycle	0.002	0.002	0.002	0.002
Walk	0.002	0.002	0.002	0.002
Telecommute	0.00	0.00	0.00	0.00

Automobile Cost Range: Accident cost estimates range from $0.05 to $0.20 per automobile mile, the maximum based on the Urban Institute estimate with a higher value of human life. 15% to 50% of these costs are considered external based on studies cited.

	Minimum	Maximum
Internal	$0.03	$0.17
External	$0.01	$0.10

Discussion

Despite the fact that accident costs are greater than other variable costs such as fuel or parking, they seldom seem to discourage driving. It is therefore interesting to consider how this cost is perceived by users. Since approximately 1/3 of accident costs are caused by drunk drivers, the overall average overstates the risk for a sober driver (drunks are irrational, so the fact that they take significant risks is not surprising). Accident costs for sober drivers are approximately $0.10 per vehicle mile. About $0.031 of this is compensated through insurance disbursements, a fixed cost since insurance companies provide little savings for reduced driving.[42] Fixed costs give users an incentive to *maximize* driving to reduce average costs. About $0.023 of accident costs are external ($0.035 per mile times 2/3 for sober drivers), so the actual internal uncompensated accident cost for a sober driver is $0.046 per mile, only 1/3 of total accident costs.

Since accident occur infrequently, individual drivers are likely to ignore or understate this cost. Surveys find that most drivers consider their driving skill above average, so typical drivers underestimate their actual accident costs. It may therefore be common for drivers to assume that their insurance payments cover the full risk they impose. Drivers may also tend to deny the possibility that they may experience uncompensated costs or impose such costs on others. Thus, it is not surprising that through a combination of fixed costs, external costs, optimism, and denial drivers are not usually influenced by the risk of accidents they impose on themselves and others, despite the high total cost it imposes.

[42] Compensated accident costs are not included in this chapter's Best Guess estimates to avoid double counting the insurance payments in Chapter 3.1.

3.4 Parking

Definition: Automobile parking costs.

Description: Automobile parking costs include capital, operating and opportunity costs of off-street employee, commercial, municipal and residential parking.[1] Cost estimates should be based on the full opportunity costs of the parking lot real estate, which is often under-assessed for tax purposes. Tax exemptions for employee parking are also considered a parking cost in terms of public revenue foregone.

Discussion: Subsidized parking is a significant cost, and a major incentive for driving. According to the 1990 Nationwide Personal Transportation Survey (NPTS), motorists reported receiving free parking for 99% of all automobile trips.[2] Approximately 95% of all workers drive to work, only 5% of whom pay their full parking costs, and about 9% pay at a subsidized rate. The majority of these parking subsidies are income tax exempt. As Donald Shoup points out, the average value of employee parking subsidies exceeds the average value of the fuel spent on a commute, yet nobody expects employers to provide free fuel, and if provided it would be taxed. Parking subsidies are estimated to increase driving by 20%-40% over levels that would occur if no subsidy were provided,[3] and are inequitable since transit riders, bicyclists, and walkers receive no comparable benefit.

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[1] To avoid double counting costs in chapters 3.1 and 3.6, on-street parking and user paid non-residential are not included as a cost in this chapter.
[2] 1990 NPTS, *Summary of Travel Trends*, USDOT (Washington DC) 1992.
[3] Donald Shoup, "Cashing Out Employer-Paid Parking," in *Curbing Gridlock*, 1994, pp. 152-199.

Figure 3.4-1 **Employee Parking Subsidy Patterns[4]**

Most commuters who drive enjoy free or underpriced parking.

Typical parking stalls are 8-10 feet wide and 18 to 20 feet deep, totaling 144 to 200 square feet. When access lanes are included, the total parking lot area per vehicle is approximately double this amount (276 to 340 square feet), allowing a total of about 125 spaces per acre.[5] The Institute of Transportation Engineers estimates surface parking lots cost an average of $1,600 per space in 1994 dollars, in addition to land costs, and parking structures average about $9,000, in addition to land costs.[6] Wegmann places the average cost for a new employee parking space at about $5,300 in 1994 dollars.[7] In addition to these market costs, parking facilities also impose non-market costs, including aesthetic degradation, stormwater concentration, and increased automobile dependency.[8]

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[4] Miller and Moffet, *The Price of Mobility*, National Resource Defense Council, Oct. 1993, p.24
[5] James Hunnicutt, "Parking, Loading, and Terminal Facilities," in *Transportation and Traffic Engineering Handbook*, Institute of Transportation Engineering/Prentice Hall, 1982, p. 651.
[6] James Hunnicutt, "Parking, Loading, and Terminal Facilities," in *Transportation and Traffic Engineering Handbook*, Institute of Transportation Engineering/Prentice Hall, 1982, p. 651.
[7] Frederick Wegmann, *Cost Effectiveness of Private Employer Ridesharing Programs: An Employer's Assessment*, Transportation Center, 1985.
[8] Peter Newman and Jeff Kenworthy, *Cities and Automobile Dependency*, Gower, 1989, pp. 122-126. Their research indicates that higher parking provisions as a percentage of urban area increase automobile dependency, promote sprawl, and reduce urban attractiveness.

Parking subsidies paid by employers and commercial businesses raise the cost of employment and consumer goods. Since the area devoted to parking typically equals the floor space of a building, current parking requirements are approximately equal to a 100% tax on building land. Some communities also directly subsidize municipal parking lots and structures. Of 1,284 cities that responded to a 1972 survey, 51% own off-street municipal parking.[9] Parking is required by most zoning laws and investment agencies, making it a fixed cost imposed on users and non-users alike. Employee parking is exempt from U.S. income tax, a benefit to drivers that can be worth up to $1,800 per year. These foregone taxes can also be considered a parking subsidy.

The number of parking spaces per automobile varies depending on land use patterns, with more parking and a higher percentage of free parking available in suburban and rural areas than in urban conditions.[10] Most commercial zoning codes require a generous amount of parking (Table 3.4-1), which is usually provided for free, resulting in a cross subsidy from non-drivers to drivers. This may be explained in part by a "prisoner's dilemma," whereby any individual store that tries to charge for parking will lose more than it can make up in customers who use other modes from slightly lower overall prices.[11] Michael Cameron emphasizes the need to reduce subsidies for non-employee parking:

> *"Studies show that when shoppers pay for parking they are more likely to shop in areas where all of their stops are within walking distance of each other, and that they are less likely to drive from place to place. This has important implications for both congestion and air quality -- especially given the impact that cold-starts have on emissions."*[12]

Estimating commercial parking subsidies is difficult because each car tends to use many such parking spaces for short periods. Lee applied parking generation rates to gross

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[9] Homburger, Kell and Perkins, *Fundamentals of Traffic Engineering*, Institute of Transportation Studies, UCB (Berkeley), 1992, p. 27-3.
[10] Herbert Levinson, "Urban Traffic Characteristics," *Transportation and Traffic Engineering Handbook*, Institute of Transportation Engineers/Prentice Hall (Englewood Cliffs), 1982, p. 298, 300.
[11] Doug Lee, *Full Cost Pricing of Highways*, Transport Research Center (Cambridge), 1993, p. 28.
[12] Michael Cameron, *Transportation Efficiency*, Environmental Defense Council (Oakland), 1991, p.42.

leasable square footage of shopping centers, and scaling that to all retail parking using dollar volume of sales to estimate that 25 million parking spaces are provided for retail customers, about one for every 7.5 registered automobiles.[13] Additional non-retail activities, such as schools, daycare centers, medical and other professional service buildings, recreational centers, and municipal facilities such as courts and post offices would increase this estimate of commercial parking.

Table 3.4-1 **Typical Zoning Requirements for Off-Street Parking**[14]

Building Type	Unit	Spaces
Office Buildings	per 1000 sq. ft.	2.5
Retail	per 1000 sq. ft.	5
Single Family Dwellings	House	1-2
Apartments	Unit	1
Hotels/Motels	Unit	1
Public Services (museums, libraries)	per 1000 sq. ft.	3.3
Hospitals	per 1000 sq. ft.	10
Theaters	per seat	0.25

Most local zoning laws require property owners to provide significant amounts of parking, which is usually provided free, effectively subsidizing driving.

In addition to direct costs, automobile parking requirements impose indirect costs in terms of environmental impacts, urban sprawl, automobile dependency, and increasing land costs. Since parking lots are typically larger than the buildings they are intended to serve, parking costs are a major reason that many businesses choose low price land at the urban edge rather than a centralized location. In commercial and industrial areas large parking lots separate buildings, reducing the viability of walking, and provisions for parking have been statistically correlated with increased automobile dependency.[15]

Increased parking requirements are unfair and regressive, since lower income households on average own fewer automobiles and pay a much larger portion of total household

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13 *Full Cost Pricing of Highways*, National Transportation Research Center (Cambridge), 1995, p.18.
14 Homburger, Kell and Perkins, *Fundamentals of Traffic Engineering*, Institute of Transportation Studies, UCB (Berkeley), 1992, p. 27-2.
15 Joel Garreau, *Edge City*, Doubleday, 1991; Peter Newman and Jeff Kenworthy, *Cities and Automobile Dependency*, Gower Press (Aldershot), 1989.

expenditures per parking space than wealthier households, and because parking requirements reduce the availability of lower priced housing.[16] One study found that requiring just one parking space per housing unit (many communities now require 2 or more) increased construction costs 18%, significantly reduced the land available for housing, and gave developers an incentive to develop fewer, larger and more expensive units.[17] As Donald Shoup concludes, "*Form no longer follows function, fashion, or even finance; instead, form follows parking requirements.*"[18]

Estimates: (Note: Although many of these estimates are presented in *per mile* units, this cost is correctly measured *per trip*. Parking costs are not affected by trip length.)

- Apogee Research estimates these parking costs in two cities:

Table 3.4-2 **Parking Costs in Two New England Cities (¢ per vehicle mile)**[19]

	Automobile		Bicycle	
	User Cost	External Cost	User Cost	External Cost
Boston, MA				
High	15.7	9.3	0.6	2.1
Medium	12.6	5.5	0.5	0.7
Low	6.9	3.7	0.3	0.6
Portland, ME				
High	5.8	10.0	0.2	0.8
Medium	1.5	2.8	0.1	0.5
Low	1.2	2.5	<0.1	0.4

- Michael Cameron estimates parking subsidies at $3.00 per day for typical commuters in Southern California, and about one cent per minute for commercial parking.[20]

- Patrick Hare estimates that parking costs account for about 10% of a typical apartment rent of $500 per month, or about $600 per year.[21]

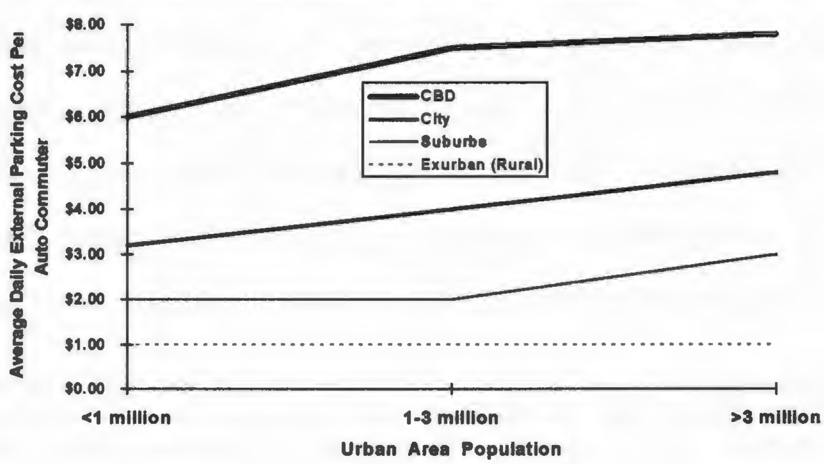
[16] Todd Litman, *Parking Requirment Impacts on Housing Affordability*, Victoria Transport Policy Institute (Victoria), 1995.
[17] Wallace Smith, *The Low-Rise Speculative Apartment*, Research Report 25, University of California Center for Real Estate and Urban Economics (Berkeley), 1964, cited in Shoup, 1994.
[18] Donald Shoup, "Cashing Out Employer-Paid Parking," forthcoming, *Journal of the American Planning Association*, June 1994, p. 18.
[19] *The Costs of Transportation: Final Report*, Conservation Law Foundation (Boston), 1994, p. 99-111.
[20] Michael Cameron, *Transportation Efficiency*, Environmental Defense Council (Oakland), 1991, p 41.

- Douglass Lee updated and expanded estimates by Don Pickrell[22] to calculate 80.9 million total free employee parking spaces worth $53 billion annually (Table 3.4-3 and Figure 3.4-2), and retail customer parking subsidies to be $18 billion. Together, employee and retail parking subsidies total $71 billion, or $0.03 per vehicle mile.[23] This total is probably low because it is based on 1980 census commute mode values (solo automobile commuting has increased), and because non-retail commercial client parking (professional services, medical services, etc.) are not included.

Table 3.4-3 **Estimate of Employee Parking Subsidies**

Location	**Urban Population**	**Commuters**	**Car Drivers**	**Avg. Daily Cost**	**Park Free**	**Park Free**
Units	Million	Million	Percent	Dollars	Percent	Million
Not Reported		8.3	50	1.00	100	4.1
Rural	<50,000	19.6	100	1.00	100	19.6
Suburbs	Under 1	13.4	85	2.00	100	11.4
	1 to 3	11.5	80	2.00	100	9.2
	Over 3	7.7	67	3.00	100	5.2
City	Under 1	15.7	74	4.00	80	9.3
	1 to 3	8.8	72	5.00	80	5.0
	Over 3	6.2	60	6.00	70	2.6
CBD	Under 1	2.3	62	8.00	75	1.1
	1 to 3	1.5	58	10.00	75	0.7
	Over 3	1.5	49	12.00	65	0.5
Total/Average		96.7	77	3.07	93	68.7

Figure 3.4-2 **Average External Parking Cost Per Automobile Commuter**



[21] Patrick Hare, et al, *Trip Reduction and Affordable Housing*, Transportation Research Board, 1991

[22] Don Pickrell, "Eliminating Employer-Subsidized Parking" in *Climate Change Mitigation: Transportation Options*, National Transportation Research Center (Cambridge), for USEPA, 1993.

[23] *Full Cost Pricing of Highways*, National Transportation Research Center (Cambridge), Jan. 1995.

- James MacKenzie et al. estimate that 86 million autos receive an average $1,000 per year in free parking, a subsidy worth $86 billion annually, or $0.039 per mile.[24]
- Peter Miller and John Moffet estimate external parking costs to range from $.008 to $.032 per vehicle mile.[25]
- Terry Moore and Paul Thorsnes estimate the total annual subsidy of non-residential off-street parking totals $200 billion, averaging 9.5¢ per mile, based on the assumption that commercial parking costs approximately equal those of commuter parking.[26]
- The Office of Technology Assessment study estimates the annual value of free off-street employee parking ranges from $37 to $66 billion, and parking for non-work trips is $64 to $132 billion. They recommend using a range of $43 to $185 billion for total external parking costs, averaging $0.02 to $0.08 per vehicle mile.[27]
- Donald Shoup and Richard Willson calculate the average employee parking subsidy in central Los Angeles in 1986 to be $3.87, worth $5.04 in 1993.[28] Willson estimates that building owners in the Los Angeles region would have to charge from $31 to $134 monthly per parking space, averaging $109 per occupied space.[29]
- Transport 2021 estimates residential parking stall costs average $746 Canadian per house and $743 per apartment. Total parking costs average $0.037 total Canadian per km (about $0.046 U.S. per mile).[30]

Variability: Parking costs and the portion of costs vary considerably depending on location and the type of driving. Costs per space are highest in large urban areas, especially in areas which require multi-story parking facilities. For example, the estimated cost per parking space is about 4 times higher in the central business district of a large city than the overall average. However, taking into account the lower portion of free parking in such areas, the average parking subsidy per automobile commuter is only about half

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[24] MacKenzie, Dower & Chen, *The Going Rate*, World Resources Inst. (Washington DC), 1992, p. 10.
[25] Miller and Moffet, *The Price of Mobility*, National Resources Defense Council, Oct. 1993, p.24
[26] Terry Moore and Paul Thorsnes, *The Transportation/Land Use Connection*, American Planning Association, Report #448/449 (Washington DC), 1994, p.49.
[27] *Saving Energy in U.S. Transportation*, U.S. Office of Technology Assessment, 1994, p. 106.
[28] Donald Shoup and Richard Willson, *Commuting, Congestion and Parking: The Employer-Paid Parking Connection*, Draft Paper, 1992, cited in Apogee Research, 1993.
[29] Richard Willson, *Suburban Parking Economics and Policy: Case Studies of Office Worksites in Southern California*, FHWA (Washington DC), Sept. 1992.
[30] Transport 2021, *Costs of Transportation People in the British Columbia Lower Mainland*, Greater Vancouver Regional District, (Vancouver), 1993, pp. 13-16.

again higher than the overall average. Parking costs tend to be relatively high per commute trip since employees typically need a space for 8 or more hours. The total value of parking for other non-work trips probably equals or exceeds that of employee parking. The cost per trip or per mile is lower however, since it is averaged over more travel.

Conclusions: Parking is a substantial cost of driving, most of which is external. Although parking imposes both market and non-market costs, only market costs will be considered here because of a lack of a lack of data, and because many non-market costs are already captured in chapters 3.10 (Equity and Option Value), 3.14 (Land Use Impacts) and 3.15 (Water Pollution and Hydrologic Impacts).

Internal Parking Costs: To avoid double counting user parking fees that are included in Chapter 3.1, only residential parking costs are considered here. Patrick Hare's estimate that an automobile parking space costs approximately $600 per year, is used to estimate an average of $0.05 per mile for a vehicle driven 12,500 miles per year. Although this estimate is for multi-family residences, it is considered a reasonable conservative estimate for the amortized cost of single family parking costs. Some residents park their cars on the street, but this seems to be balanced by others who have more off-street parking spaces than cars, so one off-street space is assumed to exist for each registered car (about 190 million in the U.S.). Rural parking space costs are estimated at half of urban due to lower land values. As described below, small cars, motorcycles, and bicycles are estimated to be 5%, 25%, and 95% cheaper to park than an average automobile. Rideshare passengers, buses, trolleys, walking and telecommuting incur no user parking costs.

Best Guess **Internal Parking Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.050	0.050	0.025	0.042
Fuel Efficient Car	0.045	0.045	0.023	0.038
Electric Car	0.045	0.045	0.023	0.038
Van	0.050	0.050	0.025	0.042
Rideshare Passenger	0.00	0.00	0.00	0.00
Diesel Bus	0.00	0.00	0.00	0.00
Electric Bus/Trolley	0.00	0.00	0.00	0.00
Motorcycle	0.040	0.040	0.020	0.033
Bicycle	0.003	0.003	0.001	0.002
Walk	0.00	0.00	0.00	0.00
Telecommute	0.00	0.00	0.00	0.00

External Parking Costs: Several estimates place average off-street parking costs around $750 per year or $3.00 per day per space,[31] and place total U.S. employee parking subsidies at between $50 and $70 billion per year. A value of $55 billion is used. Dividing that amount by 460 billion peak period[32] miles gives an average employee parking subsidy of $0.12 per commute mile. An alternative approach is to divide the $3.00 average parking space cost by 22 average commute miles and subtract 8% for commuter paid parking, which gives an estimated average external commute parking costs of $0.125 per commute mile. Based on these estimates, $0.12 per commute mile is used for Urban Peak driving.

Commercial parking subsidies are estimated using the Office of Technology Assessment's figures which indicate total average external parking costs (work plus non-work) range of $44 to $185 billion, with a $115 billion mid-point. Subtracting the $55 billion estimated for work parking from this figure leaves $60 billion. Divided by 1,840 Urban Off-Peak and Rural trips, this averages about $0.03 per vehicle mile. An estimate of $0.04 is used for Urban Off-Peak driving and $0.02 for Rural driving, to represent differences in land value.

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[31] This $750 annual cost equals about $7,500 in capital cost, $1,500 of which is surface preparation leaving $6,000 for land. Assuming 125 parking spaces per acre, this implies an average land value of $750,000 per acre for commercial real estate used for parking, not an unreasonable figure.
[32] Urban Peak travel is used to represent commuting in this exercise.

Small gasoline and electric cars can use "Compact Car" spaces, offering an estimated 20% space savings 25% of the time, for 5% total saving. Ride share passengers, buses and trolleys incur no incremental parking cost.[33] Motorcycles are estimated to use half-size parking spaces 50% of the time, for a 25% saving over an automobile, while bicycle parking costs are estimated at 5% of an automobile, due to minimal space requirements, and the ability to use otherwise unused space. Walking incurs no parking cost.

Best Guess **External Parking Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.120	0.040	0.020	0.048
Fuel Efficient Car	0.114	0.038	0.019	0.046
Electric Car	0.114	0.038	0.019	0.046
Van	0.120	0.040	0.020	0.048
Rideshare Passenger	0.00	0.00	0.00	0.00
Diesel Bus	0.00	0.00	0.00	0.00
Electric Bus/Trolley	0.00	0.00	0.00	0.00
Motorcycle	0.09	0.03	0.015	0.036
Bicycle	0.006	0.002	0.001	0.002
Walk	0.00	0.00	0.00	0.00
Telecommute	0.00	0.00	0.00	0.00

Testing these estimates: This cost can be checked by multiplying these costs by mileage:

Table 3.4-5 **Estimated 1993 U.S. Vehicle Miles Traveled (VMT)**[34]

	VMT (billions)	Parking Cost/Mile	Total Cost (billions)
Urban Peak	460	0.12	$55.2
Urban Off-Peak	920	0.04	$36.8
Rural	920	0.02	$18.5
Total	2,300		$110

Dividing this total by 2,300 billion total miles, external parking costs average $0.048 per mile overall. These are comparable to previous estimates.

[33] Curb side bus stops and pullouts do use space that might otherwise be available for on-street parking, so there is a tradeoff between buses and parking. However, this is considered a road cost rather than a parking cost.

[34] *Facts and Figures 93*, American Automobile Manufacturers Association (Detroit) p. 62, assuming 3% annual growth in VMT since 1992. Percent Urban Peak is estimated.

Automobile Cost Range: Minimum and maximum estimates are based on cited estimates.

	Minimum	Maximum
Internal	$0.03	$0.08
External	$0.03	$0.10

3.5 Congestion

Definition: Incremental costs resulting from interference among road users.

Description: Each additional vehicle on a road can interfere with other road users, especially when traffic volumes approach a road's capacity. This results in lost time, increased pollution, increased vehicle operating costs, and driver stress.

Discussion: The capacity of a road depends on various design factors such as lane widths and intersection configurations. Typical performance values are shown in tables 3.5-1 and 3.5-2 in reference to Level Of Service (LOS), a measure of roadway congestion. These tables assume ideal conditions and roads with no or few intersections. Many factors decrease this optimal performance. Traffic speed and flow on urban streets are determined primarily by intersection capacity, which is affected by traffic volumes on cross streets and the need for designated left turn signal phases on medium and high volume roads.

Table 3.5-1 **Typical Roadway Speed, Flow and Density Relationships**[1]

LOS	**Speed Range** (mph)	**Flow Range** (veh./hour/lane)	**Density Range** (veh./mile)
A	Over 60	Under 700	Under 12
B	57-60	700-1,100	12-20
C	54-57	1,100-1,550	20-30
D	46-54	1,550-1,850	30-42
E	30-46	1,850-2,000	42-67
F	Under 30	Unstable	67-Maximum

This table shows the speed, flow and density of traffic under each Level of Service (LOS) rating, a standard measure of traffic congestion.

Table 3.5-2 **Maximum Service Volumes (Passenger Cars Per Hour Per Lane)**[2]

	LOS A	**LOS B**	**LOS C**	**LOS D**	**LOS E**
4-lane Freeway	700	1,100	1,550	1,850	2,000
2-lane Highway	210	375	600	900	1,400
4-lane Highway	720	1,200	1,650	1,940	2,200

This table shows maximum traffic volume per lane for various types of roadways.

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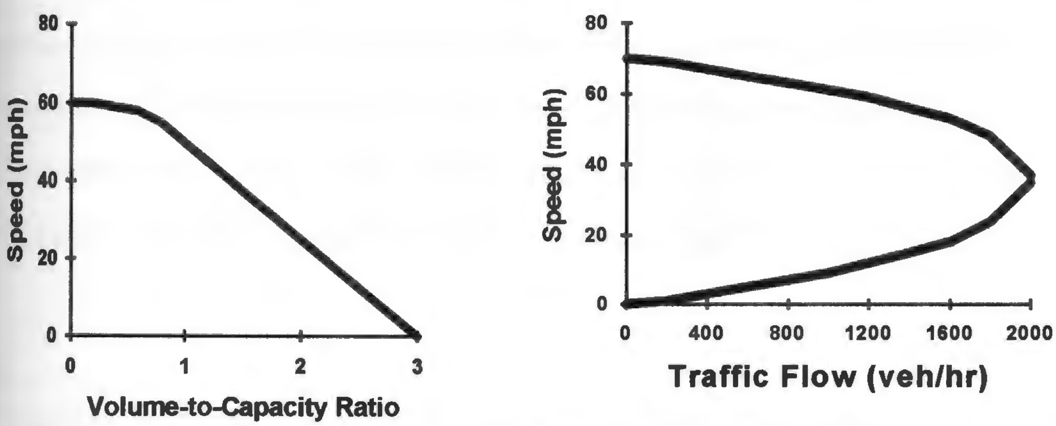
[1] Homburger, Kell and Perkins, *Fundamentals of Traffic Engineering, 13th Edition*, Institute of Transportation Studies, UBC (Berkeley), 1992, p. 4-4.
[2] Homburger, Kell and Perkins, *Fundamentals of Traffic Engineering, 13th Edition*, Institute of Transportation Studies, UBC (Berkeley), 1992, p. 8-3.

Figures 3.5-1 and 3.5-2 illustrates these relationships. Because faster traffic requires more separation between vehicles, increased traffic volume reduces a road's carrying capacity and average speed, so each additional vehicle imposes costs to other road users.[3]

A significant portion of congestion delays are associated with "traffic incidents" that are randomly distributed by time and location. According to Federal Highway Administration estimates, incidents (80% disabled vehicles and 10% accidents) account for 60 percent of delay hours.[4] Although these are random events, they only cause significant delays on roads that are already congested so are considered congestion cost. Under uncongested conditions an incident causes little or no traffic delay, but a stalled car on the shoulder of a congested road can cause 100-200 vehicle hours of delay on adjacent lanes.

Figure 3.5-1 **Speed-Density Relationship** ***Figure 3.5-2*** **Speed-Flow Relationship**



Increased traffic reduces traffic speed and flow capacity.

[3] *A Policy on Geometric Design of Highways and Streets (Green Book)*, AASHTO (Washington DC), 1990, pp. 53-97. Timothy Hau's *Economic Fundamentals of Road Pricing*, Working Paper, The World Bank (Washington DC), 1992 provides an excellent description of these functions.

[4] L. Grenzeback & C. Woodle, "The True Costs of Highway Congestion," *ITE Journal*, Mar. 1992, p.16.

Calculating Congestion Costs

There are various ways to calculate congestion externalities.[5] The analytically most correct but difficult approach is to calculate marginal delay costs to other road users resulting from an additional vehicle in the traffic stream, taking into account the speed-flow relationship for each road segment.[6] Another approach is to determine the price drivers must be charged to reduce demand to roadway design capacity. A third approach is based on the cost of increasing road capacity to an optimal level. In theory these three methods should provide converging cost values, assuming that roadway capacity is expanded based on vehicle delay costs as reflected in vehicle users' willingness to pay, but in practice they often provide different results.[7] A common but crude method for calculating congestion costs is to sum the additional travel time over free-flowing conditions.[8]

A problem with modeling congestion costs is the effects of *generated traffic*, as will be discussed in Chapter 5. If travel demand were fixed, each additional vehicle would impose a specific cost and each less vehicle would provide a specific saving. But on many roads traffic congestion maintains a self-limiting equilibrium.[9] As Wardrop observed, *"The amount of traffic adjusts itself to a barely tolerable speed."*[10] Congestion delays cause drivers to use other routes, travel at other times, shift modes, and avoid some trips. Uncongested roads attract traffic and encourage more and longer motor vehicle trips than if the same road is congested. This is called *generated traffic*.[11]

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[5] Mark Miller and Kayin Li, *An Investigation of the Costs of Roadway Traffic Congestion*, California PATH, UCB, Berkeley, 1994. Kenneth Small, *Urban Transportation Economics*, Harwood (Chur), 1992, pp. 85-94; Michael Cameron, *Transportation Efficiency*, Environmental Defense Fund (Oakland), 1991, p. 19.
[6] For an overview see Anthony Downs, *Stuck in Traffic*, Brookings Institute (Washington DC), 1992.
[7] Terry Moore and Paul Thorsnes, *The Transportation/Land Use Connection: A Framework for Practical Policy*, American Planning Association (Chicago), Report # 448/449, 1993.
[8] This is unrealistic since an economically optimized road system has at least some congestion.
[9] Kenneth Small, *Urban Transportation Economics*, Harwood (Chur), 1992, p. 112.
[10] "Wardrop's Third Principal," David Holden, *Journal of Transport Economics and Policy*, 9/89, p. 239.
[11] Anthony Downs, "Law of Peak-Hour Expressway Congestion," *Traffic Quarterly*, Vol. 16 , July 1962.

Generated traffic has three implications for assessing marginal congestion costs. First, generated travel has relatively low value because these are trips that users don't make unless traffic conditions are favorable.[12] Second, generated traffic reduces the congestion relief benefits of increased road capacity. Third, generated traffic increases total motor vehicle external costs. Many traffic models and transport investment analyses fail to incorporate these factors, which overvalues congestion reduction benefits and underestimates total costs.[13]

Internal or External Cost?

Whether congestion is an internal or external cost depends on the perspective. Since congestion is borne primarily by the same people who cause it (road users), some analysts consider it internal,[14] but as discussed in section 1.4, from an economic efficiency perspective it is external because users do not bear costs proportional to what they impose, so there is no incentive toward optimum consumption. As Franzi Poldy states,

> *"While it is true that road users bear congestion costs collectively, they make their decisions to travel individually. For each individual, a decision to travel requires only that the benefits exceed the delay (and other) costs that each traveller would expect to face on the congested road network...By deciding to join the congested traffic flow, the marginal traveller adds to the congestion, and causes a small increase in the delay experienced by each of the other users. The sum (over all road users) of these additional delays can be very much greater than the average delay (experienced by each individual) which formed the basis of the decision to travel. It is because cost bearing and decision making are separated that these costs are appropriately considered external."*[15]

Traffic congestion imposes inequitable costs on non-drivers, another reason to treat it as an externality. Bicyclists, buses, and automobiles all contribute to traffic congestion, but at

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[12] Generated traffic benefits should be assessed using the "Rule-of-Half" as described in the *Manual on User Benefit Analysis of Highway and Bus Transit Improvements* (the Red Book), AASHTO, 1977, p.26

[13] See further discussion see Chapter 5 of this report.

[14] Mark Hanson, "Automobile Subsidies and Land Use," *APA Journal*, Winter 1992, pp. 60, 68; Per Kågeson, *Getting the Prices Right*, European Fed. for Transport and Environment (Broxelles), 1993.

[15] BTCE & EPA, "The Costing and Costs of Transport Externalities: A Review," *Victorian Transport Externalities Study*, Vol. 1, Environment Protection Authority (Melbourne, Australia), 1994.

different rates per traveler. Thus, SOV drivers impose costs on car poolers and bus riders who are equally delayed in traffic (except on HOV facilities) despite the much lower cost they impose. Congestion causes delays to pedestrians, and imposes increased noise and air pollution on nearby residents. The external nature of congestion costs is also demonstrated by the considerable resources society spends to increase road capacity and implement demand management programs, only part of which are paid by automobile user fees.

Estimates:

- The AASHTO "Green Book" Table III-33 shows that buses have the congestion effects of 1.6 *Passenger-Car Equivalents* (the unit of relative congestion impacts) on highways with grades up to 4%, and higher equivalents on steeper grades.[16]
- Michael Cameron cites overall average congestion costs of $0.11 per vehicle mile in Southern California, and $0.37 per vehicle mile under congested conditions.[17] He also cites road capacity expansion costs of $.10 per average vehicle mile.[18]
- Table 3.5-3 shows marginal arterial congestion costs for various Australian cities.

Table 3.5-3 **Marginal External Congestion Costs**[19]

Peak Period Traffic	Sydney		Melbourne		Brisbane		Adelaine	
	AUS/km	US/mile	AUS/km	US/mile	AUS/km	US/mile	AUS/km	US/mile
Poor	2.63	3.34	2.23	2.83	2.46	3.12	2.28	2.90
Fair	0.57	0.72	0.50	0.64	0.55	0.70	0.37	0.47
Good	0.04	0.05	0.05	0.06	0.04	0.05	0.04	0.05
Weighted Avg.	1.04	1.32	0.48	0.61	0.60	0.76	0.19	0.24

- According to a 1986 report by the Institute of Transportation Engineers, 10% of urban driving and 16% of principal arterial driving occur under congested conditions, and these percentages are increasing.[20]

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[16] *A Policy on Geometric Design of Highways and Streets*, AASHTO (Washington DC), 1990, p. 261.
[17] Michael Cameron, *Transportation Efficiency*, Environmental Defense Fund (Oakland), 1991, p.19
[18] Steve Morrison, "A Survey of Road Pricing," *Transportation Research*, 20A/2, p.91.
[19] J.J. Dodgson, "Benefits of Changes in urban Public Transport Subsidies in the Major Australian Cities," *The Economic Record*, Vol. 62, No. 177, 1986, pp. 224-235.
[20] *Urban Traffic Congestion: What Does the Future Hold,* Inst. of Transportation Engineers, 1986, p. 7.

- Theodore Keeler, et al. estimated marginal congestion costs for San Francisco area highways. Their results are summarized in Table 3.5-1 with cost estimates updated to 1994. This is still considered one of the most comprehensive analysis of its type.

Table 3.5-1 **Marginal Highway Congestion Costs (¢/mile)**[21] (Travel time = $13.50)

	Interest	Peak	Near Peak	Day Avg.	Night Avg.	Weekend
Rural-Suburban	6%	8.1	3.3	1.8	1.2	0.3
	12%	15.6	4.5	2.4	1.5	0.3
Urban-Suburban	6%	9.9	3.6	2.1	1.5	0.3
	12%	21.0	4.8	2.4	1.5	0.3
Central City	6%	45.6	5.4	2.7	1.8	0.6
	12%	80.1	5.4	2.7	1.8	0.6

- Brian Ketcham estimates national average congestion costs at $.072 per automobile mile, citing reduced productivity, and increased vehicle operating and freight costs.[22]

- Douglass Lee cites congestion costs of about $.10 per vehicle mile in urban areas, with higher spot estimates of $.30 per vehicle mile.[23]

- Peter Miller and John Moffet estimate national congestion costs greater than $0.035 per passenger mile for all driving, with much higher costs on congested roads.[24]

- Herbert Mohring and David Anderson estimate average congestion costs for Twin City roads shown in Table 3.5-2.

Table 3.5-2 **Average Marginal Congestion Costs**[25]

	Morning Peak	Afternoon Peak
All Road Links	$0.207	$0.17
Expressways	$0.236	$0.201

- U.S. research cited in an OECD report indicates that motorcycles on urban freeways impose 0.5 passenger car units (PCU) of congestion when traffic per lane is less than 600 vehicles per hour (VPH), but this increases to 1 PCU at 1,800 VPH.[26] Buses on urban freeways are estimated to impose 1.2 PCU at less than 1,000 VPH, and 1.8 at 1,800+ VPH. On urban arterials, buses are estimated to impose 1.2 PCU at LOS B, 1.3 PCU at LOS D, and 1.7 PCU at an intersection. This does not appear to include stopping to pick up passengers.

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[21] Theodore Keeler, et al., *The Full Costs of Urban Transport: Part III Automobile Costs and Final Intermodal Cost Comparisons*, Institute of Urban and Regional Development (Berkeley), 1975, p. 47.
[22] Brian Ketcham, *Making Transportation Choices based on Real Costs*, Oct. 1991, p. 9
[23] Douglass Lee, *An Efficient Transportation and Land Use System*, January 1989, p.5
[24] Miller and Moffet, *The Price of Mobility*, National Resources Defense Council, Oct. 1993, p.23
[25] Herbert Mohring and David Anderson, *Congestion Pricing for the Twin Cities Metropolitan Area*, Dept. of Economics, University of Minnesota (Minneapolis), January 1994.
[26] *Impacts of Heavy Freight Vehicles*, OECD (Paris), December 1982.

- The Office of Technology Assessment study estimates annual congestion costs at $129 to $150 billion, averaging $0.056 to $0.065 per vehicle mile, but also points out that some estimates may overstate national congestion growth and total costs.[27]

- Robert Repetto, et all. modeled congestion costs on five classes of congested roadways, covering about half of total U.S. vehicle travel.[28] They concluded that appropriate congestion fees average $0.04-0.05 per vehicle mile over these roads, and range as high as $0.21 per vehicle mile. They estimate total direct national congestion costs at $44 billion annually, and as high as $98 billion annually when additional accident costs are included.

- Transport Concepts estimates truck interference costs (congestion and delays to other traffic) at $0.62 per ton mile for intercity semi-trailer trucks and $0.79 per ton mile for B-Train trucks ($0.52 and $0.64 Canadian per tonne kilometer respectively).[29]

- A Transportation Research Board special committee report cities several congestion pricing studies that provide estimates of optimal congestion prices (which are considered to represent congestion costs) ranging from about $0.05 to $0.36 per vehicle mile on congested urban roads, with averages of $0.10 to $0.15.[30]

- A U.S. General Accounting Office estimates that productivity losses from highway congestion cost the nation as much as $100 billion annually.[31]

- A recent USDOT/FHWA study estimates annual congestion costs at $43.2 billion.[32]

- Ken Small, et al. estimate that large vehicles such as trucks and buses contribute 1.5 to 5 times more to congestion than automobiles, depending on road conditions.[33]

- One traffic model estimates that bicycles going straight through an intersection cause 0.2 of the congestion of an average car.[34] However, this overstates bicycles' overall congestion impacts since they are prohibited from freeways, where congestion costs are highest, and tend to use alternatives to congested roads when possible.[35]

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[27] *Saving Energy in U.S. Transportation*, U.S. Office of Technology Assessment, 1994, p. 108, 114.
[28] Robert Repetto, et al., *Green Fees: How a Tax Shift Can Work of the Environment and the Economy*, World Resources Institute (Washington DC), 1992.
[29] *External Costs of Truck and Train*, Transport Concepts (Ottawa), October 1994, p.23.
[30] *Curbing Gridlock*, TRB, National Academy Press (Washington), 1994, Appendix B.
[31] *Smart Highways: An Assessment of Their Potential to Improve Travel*, U.S. General Accounting Office (Washington DC, 1991). The quality of this estimate is uncertain.
[32] D. Schrank, S. Turner and T. Lomax, *Estimates of Urban Roadway Congestion*, USDOT, 3/1993
[33] Kenneth Small, Clifford Winston and Carol Evans, *Road Work*, Brookings Institute, 1989, p. 12.
[34] Homburger, Kell and Perkins, *Fundamentals of Traffic Engineering, 13th Edition*, Institute of Transportation Studies, UCB (Berkeley), 1992, p. 8-11.
[35] Todd Litman, "Bicycling and TDM," *Transportation Research Record 1441*, 1994, p. 134-140.

Variability: Congestion varies by location, time, and, to a lesser extent, the type of vehicle. Congestion is greatest in urban areas, but is increasingly a problem in suburban and some rural areas.[36]

Conclusions: The magnitude of traffic congestion and how this problem compares with other transportation costs depends on how congestion is measured and various assumptions about its impacts. Congestion is clearly a significant cost and an externality in terms of economic efficiency. This cost is primarily associated with Urban Peak travel (including suburban areas) but a moderate amount of congestion is associated with Urban Off-Peak travel in many areas. The cost is probably highest on urban highways, but congestion costs on major urban arterials appear to be almost as significant.

The simple existence of congestion costs does not necessarily demonstrate that road capacity needs to be increased. From an economic efficiency perspective eliminating all congestion is inappropriate since it would require a vastly over-built and therefore suboptimal road system. Urban traffic congestion must be expected because providing capacity to accommodate unlimited peak-period travel demand would not be cost effective and because congestion is self limiting.

Viable estimates of total U.S. congestion costs range from $43.2 to $150 billion per year. $100 billion is used as a starting point for this study.[37] Assuming that 20% of all driving and 80% of congestion costs occur under Urban Peak conditions,[38] and 2,300 billion miles are driving annually, the average cost is about $0.17 per Urban Peak mile ([$100 x 80%] / [2,300 x 20%]). Urban Off-Peak driving represents 40% of driving and is estimated here

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[36] Robert Cervero, *Suburban Traffic Congestion: Is There a Way Out?*, City and Regional Planning, UCB (Berkeley), 1991.

[37] Since the total value of U.S. vehicle occupant travel time is estimated at $900 billion per year, this indicates that congestion increases travel costs overall by about 11%. See *Saving Energy in U.S. Transportation*, Office of Technology Assessment, 1994 p. 108.

[38] About 60% of driving is urban and about 33% occurs during peak periods, *Facts and Figure '92*.

to incur 20% of congestion costs, for an estimate of $0.02 ([$100 x 20%] / [2,300 x 40%]). Rural driving is not considered to experience significant congestion costs. This estimate is somewhat lower per mile than marginal highway congestion cost estimates such as those by Keeler, et al (Table 3.5-1), but not unrealistic considering that it includes non-highway driving, which is likely to have lower congestion costs. However, this probably represents a lower bound and significantly higher congestion costs are likely to exist in heavily congested areas.

Fuel efficient and electric cars, vans and motorcycles have the same congestion costs as an average automobile. Additional passengers impose no additional congestion. Buses and trolleys are considered to impose twice, and bicycles 5% of the congestion costs of an average automobile. Walking and telecommuting impose no significant congestion cost.

Best Guess **Congestion Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.17	0.02	0.00	0.042
Fuel Efficient Car	0.17	0.02	0.00	0.042
Electric Car	0.17	0.02	0.00	0.042
Van	0.17	0.02	0.00	0.042
Rideshare Passenger	0.00	0.00	0.00	0.00
Diesel Bus	0.34	0.04	0.00	0.084
Electric Bus/Trolley	0.34	0.04	0.00	0.084
Motorcycle	0.17	0.02	0.00	0.042
Bicycle	0.009	0.001	0.00	0.002
Walk	0.00	0.00	0.00	0.00
Telecommute	0.00	0.00	0.00	0.00

Automobile (Urban Peak) Cost Range: Minimum and Maximum estimates are based on the literature cited above.

Minimum	Maximum
$0.02	$0.06

3.6 Road Facility Costs

Definition: Roadway facility costs required for automobile use not borne by user fees.

Description: Road facility costs include the costs of road construction and maintenance, land acquisition, financing expenses, and the portion of roadway support facilities and programs required for automobile traffic. To avoid double counting costs in Chapter 3.1, only the portion of these costs not paid by users are included here.

Discussion: Many people assume that fuel taxes and vehicle fees pay all roadway facility costs, but this is not so. Although these charges cover most highway construction and maintenance costs, a major portion of road and street costs in North America are funded by local property and sales taxes. If revenues from driving met all road construction costs, society could be indifferent to increases in traffic volumes on uncongested roads because increased revenue would offset costs. In practice, marginal roadway costs almost always exceed marginal revenues. Communities must either endure increased traffic congestion or subsidize roadway construction.

The roadway facility costs imposed by different road users has been widely studied and various models have been developed determine the allocation of these costs.[1] Capital and operating costs are often handled separately.

Capital Costs

Capital costs include land, facilities (roads), and equipment (signals, signs, etc.). Since most current capital improvements are associated with reducing congestion, cost allocated

[1] Ken Small, Clifford Winston and Carol Evans, *Road Work*, Brookings Institute (Washington DC), 1989.

between vehicle classes is based primarily on the road space each requires. The majority of this charge is allocated to private automobiles since they account for about 90% of traffic.

Capital costs borne by general taxes (typically, local property taxes, sales taxes, and special local assessments) represent an external cost since they are not based on road use. People who place heavy costs on the road system, such as those who drive large vehicles during rush hour may pay less of these taxes than others who never drive. This implies a subsidy of driving. Current North American road funding involves another more subtle subsidy. Most capital road funding does not rely on cost recovery required in most other economic sectors or for other transport modes, such as rail. Instead, current road users finance improvements for the benefit of future users, which may or may not include themselves, and capital assets are written off when completed. Douglass Lee points out that this practice of pay-as-you-go roadway funding, and treating past road capacity expenditures as sunk cost represents an undercharging of road users:[2]

> *"Current highway finance practice finances most improvements out of current revenues, eliminating the need for borrowing. If highway users -- who are also highway investors -- don't have to pay interest on capital improvements, why should they be charged for it? The reason is that money deposited in a highway trust fund earns interest at whatever rate the U.S. Treasury is paying, and that interest is foregone when money is spent. There is no way to pretend that capital investments have no opportunity cost to the funds committed to them. Equally important, the amount spent one year bears little relationship to the value of the capital consumed in that year. If the system is wearing down faster than it is being rebuilt, for example, current users are living off of previous users/taxpayers who built up the capital stock.*
>
> *If the original investment is worthwhile, it should be earning -- over its lifetime -- a rate of return at least equal to the market rate for low-risk investments. If the asset continues to be used as a highway, then implicitly it is worth what it cost, including interest on the outstanding balance. To fail to charge users enough to cover the interest, then, is a subsidy to users, in the form of a zero-interest loan. An upper bound on the opportunity cost, using this method, would be the (depreciation)*

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[2] Herbert Mohring and Mitchell Harwitz also emphasize that road user charges should incorporate amortized values for all construction, maintenance, and depreciation costs in *Highway Benefits: An Analytical Framework*, Northwestern University Press (Evanston), 1965.

replacement cost of the facility, times the current interest rate. A neutral approach, then would be to measure the replacement costs of the existing system, annualize that cost, and recover that amount each year. Replacement cost would be stated in dollars of the current year, hence revenues would keep pace with inflation."[3]

Operating Costs

These are the short run marginal costs of the road system, which consist primarily of maintenance expenditures. Most road maintenance cost, including resurfacing, bridge replacement and other repairs are attributed to motor vehicle impacts and needs. Road wear increases by approximately the third power of vehicle axle weight, so a heavy truck imposes maintenance costs hundreds of times greater than an automobile.[4] The cost of increasing road surface thickness to accommodate heavy vehicles is also allocated to those vehicles. Studded tires also incur costs that are significant in many areas, estimated at 15% of road maintenance costs in Norway, which is probably representative of colder areas in North America.[5] Some road deterioration occurs from weathering, which varies from about 2% per year in mild climates up to 7% or more in areas with extreme winters.[6]

Road facility costs are greater than current expenditures due to deferred maintenance that will increase future costs. According to the U.S. Federal Highway Administration, annual investments of over $60 billion (three times current expenditures) are needed to maintain the national road system at acceptable standards.[7]

Equitable user charges should therefore include recovery of capital investment based on each vehicle's marginal demand for road space, road durability, and maintenance. The

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[3] Douglass Lee, *Full Cost Pricing of Highways*, National Transportation Systems Center (Cambridge), Jan. 1995, p.13.
[4] Kenneth Small, Clifford Winston and Carol Evans, *Road Work*, Brookings Institute, 1989, p. 11.
[5] Per Kågeson, *Getting the Prices Right*, European Fed. for Transport & Environment, 1993, p. 150.
[6] Kenneth Small, Clifford Winston and Carol Evans, *Road Work*, Brookings Institute, 1989, p. 11.
[7] *1991 Status of the Nation's Highways and Bridges*, USDOT (Washington DC).

distribution of costs is summarized by Small et al. in the book Road Work.[8] With this information it is possible to develop road user charges based on marginal costs that does nor require cross subsidies between user classes, or from users in one time period to another. If user fees are insufficient to cover the cost of a roadway, society may be better off abandoning the road and using the resources elsewhere. Douglass Lee comments:

> *"a capital asset that continues to function as a highway should be earning revenues at least as great as the interest on the invested capital plus depreciation, plus operating costs. To earn less implies that the long run costs are not justified, and the road ought to be phased out of use. What is desired is a capital cost that includes actual depreciation plus interest, and which will recover the replacement cost of the asset over its lifetime."*[9]

Lee is simply suggesting that standard investment criteria be applied to roads. Road users should pay a return on the capital expenditures that created and maintain roadways. Roads that cannot be justified economically should be decommissioned so their resources are available for other productive uses. Failing to do this results in over-investments in roads and under-investments in other forms of transportation, other economic activities, and other uses of land. Underpricing and over investment in roads may have been justified decades ago when developing a networked road system was a strategic national goal, but contemporary sensibilities are attuned to the significant environmental damage caused by roads, the need to limit access to the few wild areas left, and the economic inefficiency implied by building and maintaining roads where social costs exceed social benefits.

Other Road Uses

It is sometimes argued that roads serve purposes other than automobile travel, so a portion of their cost should be borne by all of society. Even people who never use an automobile need access to their residence for delivery of goods and services, emergency

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[8] Ken Small, Clifford Winston and Carol Evans, *Road Work*, Brookings Institute (Washington DC), 1989.
[9] Douglass Lee, *Full Cost Pricing of Highways*, USDOT, National Transportation Systems Center (Cambridge), Sept. 1993, p.24.

vehicles, for walking and public transit, and because road rights-of-way contain public utility lines such as wires and pipe. One way to address this problem is to establish a standard of "basic access" that residents require no matter how little they use an automobile directly. In practice this need can be satisfied by a 10 or 12 foot right-of-way with a single lane of gravel or light pavement, which is the quality of road typically chosen when users pay for their own driveway and on campus-type developments. Roadway costs beyond this should be allocated to motor vehicle use.

Pre-automobile cities typically devoted less than 10% of land area to roads, while newer automobile dependent cities devote up to 30% of land area to roads, implying that 50 to 75% of road area in such cities is needed specifically to satisfy the needs of automobiles.[10] Since nearly all communities have well-developed roadway systems that easily satisfy minimal access needs, the costs of increasing existing road capacity can be charged to motor vehicle use. Pedestrian and bicycle facility costs could also be charged to driving if automobile traffic degrades the bicycling and walking environment, requiring facilities separated from the roadway. This implies that most current roadway construction and maintenance costs are the responsibility of motor vehicle users.

Estimates:

- The American Automobile Manufacturers Association states that 1992 highway user fees total $54.8 billion, including the federal excise tax on trucks, while road spending totaled $81.6 billion, leaving $26.8 billion in external costs.[11]
- Apogee Research estimated state, federal and local capital and operating costs for various modes in Boston, MA and Portland, ME at high, medium and low densities.[12]

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[10] Harry Dimitriou, *Urban Transport Planning, A Developmental Approach*, Routledge (NY), 1992, p. 136; Herbert Levinson, *Transportation and Traffic Engineering Handbook*, Institute of Transportation Engineers/Prentice Hall (Englewood Cliffs, NJ), 1982, p. 256.

[11] AAMA, *Facts and Figures '93*, p. 62, 78.

[12] Apogee Research, *The Costs of Transportation: Final Report*, Conservation Law Foundation (Boston), 1994, pp. 121-137, 155-157.

The sum of road costs for automobile use range from 5.4¢ per vehicle mile for expressway driving in Boston, to 0.6¢ for non-expressway driving in Portland. They also found that needed facility maintenance is being deferred, adding 1.2¢ per expressway vehicle mile, and 2.1¢ for non-expressway driving. Their analysis includes the estimates of relative costs per vehicle mile for three modes listed in Table 3.6-1.

Table 3.6-1 **Apogee Road Cost Factors for Three Modes (per vehicle)**

Mode	State Capital Costs	State Maint. Costs	Local Costs
Automobile	0.683	0.719	0.701
Bus	1.81	3.42	2.62
Bicycle	0.34	0.014	0.23

These factors show relative costs of three vehicle classes.

- The California Energy Commission estimates infrastructure maintenance and road repair costs at $0.006 per mile for automobiles and $0.12 per mile for buses.[13]

- The California Department of Transportation's 1987 *Highway Cost Allocation Study* estimated the cost per vehicle mile shown in Table 3.6-2.

Table 3.6-2 **Caltrans Highway Cost Allocation Values (per vehicle)**

Vehicle Class	Capital Costs (millions)	Maintenance Costs (millions)	Total Cost (millions)	Annual Miles (billions)	Unit Cost (1987$/VMT)	Unit Cost (1994$/VMT)
Automobiles	$1,035.4	1,150.2	2,185.6	158	0.014	0.018
Motorcycles	$8.2	12.3	20.5	1.5	0.008	0.010
Pickups and vans	$263.2	376	639.2	36.3	0.018	0.023
Recreational Veh.	$48.4	59.1	107.5	4.4	0.024	0.031
Buses	$11.3	11.1	22.4	0.9	0.025	0.032
Trucks	$613.7	490.4	1,104.1	13.9	0.079	0.101
All vehicles	$1980.2	2,099	4,079.2	215	0.019	0.024

- Ken Casavant and Jerry Lenzi estimate the roadway damage costs of overloaded trucks to average from about $0.08 per mile to $2.50 per mile, depending on how much they are overloaded. As a base cost they cite estimates that 40-ton trucks impose road damage costs of $0.01 to $0.06 per ton on state highways, and 50% higher costs on county roads.

- Automobile user payments (fuel taxes vehicle registration fees) cover 56% of roadway network expenditures in Wisconsin.[14] Fuel taxes would need to increase approximately $0.35 per gallon to fund all current road expenses.

- Theodore Keeler et al. estimate road maintenance costs at $.0015 per vehicle mile.[15]

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[13] California Energy Commission, *1993-1994 California Transportation Energy Analysis Report*, California Energy Commission (Sacramento), Feb. 1994, p. 29.
[14] Cambridge Systematics, *Highway Cost & Pricing Study*, Wisconsin DOT (Madison), Sept. 1994.
[15] T. Keeler, et al, *The Full Costs of Urban Transport, III* 1975, p.52, Estimates updated to 1994 dollars.

- Brian Ketcham estimates U.S. roadway maintenance costs at $.001 per automobile vehicle mile and $.45 per vehicle mile for heavy trucks.[16]

- Douglass Lee identifies the road system externalities described in Table 3.6-3. He also recommends charging a state level service tax for road use to be consistent with other economic activities, totaling $15.9 billion a year, or about $0.007 per vehicle mile.[17]

Table 3.6-3 **Lee's Estimates of Road System Externalities**

Costs	Billions of Dollars
Construction Expenditures	$42.5
Interest	26.3
Pavement, ROW, and structure maintenance	20.4
Administration and research	6.9
Total roadway expenditures	**$96.1**
Minus $55 billion road user payments	$96.1 - $55.0 = 41.1
Subsidy per mile (assuming 2,300 Billion VMT)	**$0.018**

- Peter Miller and John Moffet give maintenance costs per mile in Table 3.6-4, and total U.S. maintenance costs of $48.3 billion per year.[18]

Table 3.6-4 **Roadway Maintenance Cost Estimates**

Road Class	Urban Car $/VMT	Urban Truck $/ESAL	Rural Car $/VMT	Rural Truck $/ESAL
Interstate	0.014	0.29	0.005	0.10
Arterial	0.038	0.76	0.012	0.24
Collector	0.037	0.74	0.016	0.32
Local	0.046	0.92	0.029	0.58
Average	0.033	0.677	0.015	0.31

ESAL = Equivalent Standard Axle Load of 18,000 lbs

- Ken Small et al. use U.S. Federal Highway Administration statistics to determine that user taxes and tolls accounted for 62% of 1985 road disbursements.[19]

- The Office of Technology Assessment study estimates U.S. annual road facility costs at $77 billion, and user taxes and fees to average $44 billion per year, for a net external cost averaging about $0.014 per vehicle mile.[20]

- Transport 2021 estimates road maintenance costs to average $0.013 Canadian per km ($0.016 U.S. per mile).[21]

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[16] *Making Transportation Choices Based on Real Costs*, Konheim & Ketchem (New York), Oct. 1991

[17] Douglass Lee, *Full Cost Pricing of Highways*, USDOT, National Transportation Systems Center, (Cambridge), January 1995, p. 12.

[18] *The Price of Mobility*, National Resource Defense Council (Washington DC), Oct. 1993, p. 10.

[19] Kenneth Small, Clifford Winston, Carol Evans, *Road Work*, The Brookings Institute, 1989, p. 2.

[20] *Saving Energy in U.S. Transportation*, U.S. Office of Technology Assessment, 1994, p. 105-107.

- Transport Concepts estimates that trucks impose infrastructure costs averaging $0.82 per ton mile ($0.67 Canadian per tonne kilometer), including road capacity, road maintenance and roadway services.[22] They estimate that although big trucks make up only about 9% of vehicle traffic they account for about 25% of roadway costs. Rail infrastructure costs are considered completely internalized by rail companies.
- The USDOT's most recent cost allocation study concludes that an equivalent standard axle load (ESAL) of 18,000 lbs. incurs a road maintenance cost of $0.09 per mile on rural interstate highways, $0.66 on urban arterials and $0.80 on local urban streets.[23]

Variability: Road costs depend on the type of vehicle, how much it is used, and how much it contributes to traffic congestion.

Conclusions: Roadway costs include current capital and maintenance expenditures, a return on past capital investments in roads, and future costs from deferred maintenance. These costs can be allocated between different vehicle classes based on their use of road space and road damage. Although even people who never travel by automobile use roads for walking and other purposes, virtually all current road expenditures result from vehicle needs so costs are allocated to them. The 1987 Caltrans cost allocation study provides relative costs per vehicle. However, these understate total costs because they exclude deferred maintenance and return on investment costs. The Caltrans $0.024 per mile average cost estimate times 2,300 billion total miles gives a total cost of $55.2, which is 57% of Douglass Lee's $96.1 billion estimate of total roadway costs.[24] Scaling up the Caltrans gives total cost estimates shown in Table 3.6-5. The third column shows this cost net of $54.8 billion annual user fees, to indicate the external cost component.

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[21] Transport 2021, *Costs of Transporting People in the British Columbia Lower Mainland*, Greater Vancouver Regional District (Vancouver), 1993, pp. 25-26.
[22] *External Costs of Truck and Train*, Transport Concepts (Ottawa), October 1994, p.26.
[23] FHWA *Cost Allocation Study*, 1982 p. E-25, table 3, cited in *Road Work*, p. 15.
[24] *Facts and Figures 93*, American Automobile Manufacturers Association (Detroit) p. 63.

Table 3.6-5 **Roadway Cost Allocation (1994 dollars per mile)**

Mode	Caltrans Estimate	Total Cost Estimate	External Costs
Automobiles	0.018	0.031	0.013
Motorcycles	0.010	0.017	0.007
Pickups and vans	0.023	0.04	0.017
Buses	0.032	0.056	0.024
Trucks	0.101	0.175	0.075

This table shows Caltrans vehicle cost allocation scaled up to include total costs estimated by Douglass Lee. The left column shows this cost net of fuel taxes.

These values are used to calculate Best Guess cost estimates. Miller and Moffet indicate that urban road costs are higher than rural road costs per vehicle mile, so urban driving costs are increased by 25% and rural costs are decreased by 25%. Since electric vehicles do not pay fuel taxes dedicated to roads, all of their road costs are considered external. The marginal maintenance cost of a rideshare passenger is considered too small to count. Since public transit buses are exempt from some fuel taxes their total cost is used, but this would not be appropriate for private buses that do pay fuel taxes or where such exemptions do not exist. A trolley that travels on tracks does not incur road wear costs, but comparable public costs are required to maintain rails and right-of-way. Bicycles cause no pavement wear and impose minimal demands on road space so their cost is estimated to be 5% of an automobile. Walking and telecommuting incur no road facility costs.

Best Guess **Road Facility Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.016	0.016	0.010	0.014
Fuel Efficient Car	0.016	0.016	0.010	0.014
Electric Car	0.038	0.038	0.023	0.032
Van	0.021	0.021	0.013	0.018
Rideshare Passenger	0.00	0.00	0.00	0.00
Diesel Bus	0.070	0.070	0.042	0.059
Electric Bus/Trolley	0.070	0.070	0.042	0.059
Motorcycle	0.009	0.009	0.005	0.007
Bicycle	0.001	0.001	0.000	0.001
Walk	0.00	0.00	0.00	0.00
Telecommute	0.00	0.00	0.00	0.00

Automobile Cost Range: Minimum and Maximum values are based on estimates cited.

Minimum	Maximum
$0.01	$0.03

3.7 Roadway Land Value

Definition: Opportunity costs of land used for roadways.

Description: Roadway land value costs include the value of land used for road rights-of-way and other public facilities dedicated for automobile use. This cost could also be defined as the rent that users would pay for roadway land if it were managed as a utility, or at a minimum, the taxes that would be paid if road rights-of-way were taxed.

Discussion: Approximately 60,000 square miles of land in the U.S. are devoted to roadway rights-of-way, about 2% of the nation's total surface area. In Europe this is estimated to be a somewhat smaller 1.3 percent.[1] It is much higher in developed areas where land values are highest. In modern urban areas, 25%-30% of land is devoted to streets, and even higher percentages in commercial centers.[2] Unlike other public land uses, such as parks and forests, roadways provide little secondary environmental benefits such as wildlife habitat or timber production. Roadway land value is often considered a "sunk" cost. Émile Quinet for example argues that land which has long been used for roads incurs no social cost, but there is no reason that the opportunity cost of this resource should be ignored. Douglass Lee states, *"Land in highway right-of-way has alternative uses, and this value is included in published figures only when the purchase of new land is a part of current expenditures. Normally, any long-lived business investment is expected to earn a rate of return at least equal to the interest rate on borrowed funds."*[3]

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[1] National Academy of Sciences, *Policy Implications of Greenhouse Warming*, 1991, cited Miller, 1993.
[2] Harry Dimitriou, *Urban Transport Planning*, Routledge (NY), 1992, p. 136; Herbert Levinson, *Transportation and Traffic Engineering Handbook*, Prentice Hall (Englewood Cliffs, NJ), 1982, p. 256; Émile Quinet, "The Social Costs of Transport: Evaluation and Links With Internalisatiion Policies," in *Internalising the Social Costs of Transport*, OECD (Paris), 1994, p. 54.
[3] Douglass Lee, *An Efficient Transportation and Land Use System*, National Transportation Research Center (Cambridge), 1992.

Some authors argue that since roads often increase adjacent real estate values, that roadway land provides a positive rather than negative social value.[4] It is true that *access* (defined in Chapter 1) increases land value. But to assume that driving is the only form of access ignores differences in the amount of land required by different modes.[5] Modes such as driving, which require more land, should be charged this incremental costs.

As discussed in Chapter 3.6, a portion of the road system can be considered necessary for basic access to residents (including utility service lines such as water, sewer and power) whether they drive or not, the cost of which could be allocated to all community members. This is estimated at 25% to 50% of the total roadway area by various sources. For example, Harry Dimitriou states that pre-automobile cities typically devote less than 10% of land to streets, while modern, automobile-oriented cities devote up to 30%.[6] This portion can be subtracted before assigning roadway land value costs to automobile use.

Estimates:

- Ketcham and Komanoff assume that streets constitute 33% of urban land area, half of which is needed for basic access, to calculate the annualized value of land for automobiles to be $66.1 billion, or $0.03 per vehicle mile.

- Douglass Lee applies the FHWA's prototypical land acquisition cost per mile for 9 roadway classes to the entire U.S. road system to estimate total land value and calculate annual interest forgone to be $74.7 billion, or $0.034 per VMT.[7] He considers the FHWA's estimate to be conservative.

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[4] Émile Quinet, "The Social Costs of Transport: Evaluation and Links With Internalisatiion Policies," in *Internalising the Social Costs of Transport*, OECD (Paris), 1994, p. 55.
[5] For an interesting discussion of relative land use requirements of various modes see Eric Bruun and Vukan Vuchic, *Introduction and Historical Review of Time-Area Concept with Example New Application in Urban Land Use Analysis*, Transportation Research Board Annual Meeting, Paper 950296, 1995.
[6] Harry Dimitriou, *Urban Transport Planning*, Routledge, (NY), 1993, p. 136.
[7] *Full Cost Pricing of Highways*, National Transportation Systems Center (Cambridge), 1995, p. 11.

- Émile Quinet provides a European estimate of the relative land use area of different modes shown in Table 3.7-1.[8] This indicates that automobiles require approximately 4 times the road space as a bicycle or motorcycle, and 10 to 40 times that of buses.[9]

Table 3.7-1 **Land Use Costs By Mode (m^2 per hour)**

Mode	Use	Parking	Traffic	Total
Bicycles and Motorcycles	Work (9 hours)	13.5	7.5	21
"	Leisure (3 hours)	4.5	7.5	12
"	Shopping (1.5 hours)	2.5	7.5	10
Automobiles (1.33 passengers)	Work (9 hours)	68	17	85
"	Leisure (3 hours)	23	17	40
"	Shopping (1.5 hours)	11	17	28
Bus (daily average: 20 pass.)	Normal Roads	0	7.5	7.5
"	Bus Lane	0	30	30
Bus (peak period: 80 pass.)	Normal Roads	0	2	2
"	Bus Lane	0	7.5	7.5

- Transport 2021 calculates the value of road land dedicated to motor vehicle use in the Vancouver area to be worth $578 million a year when amortized at 10%, based on 30% of adjacent land's assessed values.[10] This averages $0.047 Canadian per km, or $0.059 U.S. per mile, or almost $0.20 if the land is assessed at its full value.

Variability: Road land costs are based on vehicle use (which creates demand for roads) and varies depending on location, with higher land market values in urban areas, and higher non-market values in areas with high environmental worth.

Conclusions: Land used for roads has an opportunity cost. There is no reason to exclude the value of this resource in transport cost analysis. To determine what should be charged to motor vehicles, it is appropriate to first subtract the portion of the road system that provides basic access, which is defined as a single lane. In most cases this represents about 25% of paved road area and a smaller portion of road rights-of-way. The remaining 75%+ is charged based on VMT. Although large vehicles may require more road space under

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[8] Émile Quinet, "The Social Costs of Transport: Evaluation and Links With Internalisatiion Policies," in *Internalising the Social Costs of Transport*, OECD (Paris), 1994, p. 55.

[9] This appears to underestimate motorcycle roadspace needs, at least in the U.S. where they are large and normally take a full lane, and overstate bicycle roadspace needs.

[10] *Cost of Transporting People in the British Columbia Lower Mainland*, Greater Vancouver Regional District (Vancouver), 1993, p. 27.

congested conditions, this is not considered significant in terms of the total amount of land allocated to road right-of-way.

Douglass Lee's estimate that roadway land is worth $75 billion per year is a reasonable starting point. Subtracting 25% of this cost for basic access leaves a $56 billion annual cost. Divided by 2,300 billion VMT, this averages $0.024 per mile, which is applied to all motor vehicles. Although urban land values are higher, urban roads receive greater use per lane mile, so average costs per vehicle mile are considered to be comparable for both urban and rural travel. Bicycles are estimated to require 5% of an average automobile's road space, while rideshare passengers, walking, and telecommuting require none.

Best Guess **Roadway Land Value Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.024	0.024	0.024	0.024
Fuel Efficient Car	0.024	0.024	0.024	0.024
Electric Car	0.024	0.024	0.024	0.024
Van	0.024	0.024	0.024	0.024
Rideshare Passenger	0.00	0.00	0.00	0.00
Diesel Bus	0.024	0.024	0.024	0.024
Electric Bus/Trolley	0.024	0.024	0.024	0.024
Motorcycle	0.024	0.024	0.024	0.024
Bicycle	0.001	0.001	0.001	0.001
Walk	0.00	0.00	0.00	0.00
Telecommute	0.00	0.00	0.00	0.00

Automobile Cost Range: The minimum represents a low estimate of property values. The upper range is based on a full value assessment of the Vancouver Region road system, taking into account that roads outside of urban center have lower value.

Minimum	Maximum
$0.01	$0.10

3.8 Municipal Services

Definition: Costs of municipal services for motor vehicles not funded by user fees.

Description: Municipal service costs include policing, emergency response, planning, courts, street lighting, parking enforcement, and traffic safety education provided for motor vehicle use but are not funded from driver fees or fines.

Discussion: Automobile use requires a variety of public services. At the municipal level these are funded largely through local taxes. A number of studies examine these costs. Some costs in these studies overlap other cost categories in this report, such as road facility costs, and must be subtracted to avoid double counting.

According to Stanley Hart's analysis of the City of Pasadena's 1982-83 budgets, approximately 40% of police department, 15% of the fire department, 16.4% of paramedic services, and a major portion of public works, capital improvement, and debt service budgets should be charged to automobile use.[1] In his analysis Hart subtracts the cost of providing minimal access for pedestrians, public service, and emergency vehicles when calculating automobile roadway costs. He concluded that automobile-related expenditures totaled $15.7 million, 75% of which came from local general taxes instead of user fees.

Daniel Ridgeway's 1990 analysis of Denver City and County budgets indicates a similar portion of municipal costs are devoted to automobile services. He calculated that about 40% of police department activities, 15% of fire department, and a major component of public works, capital facility expenditures, and municipal debt should be allocated to

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[1] Stanley Hart, "An Assessment of the Municipal Costs of Automobile Use," self published graduate studies report (Pasadena) 1985, p.14.

automobile use.[2] Additional costs were also mentioned but not included in these estimates, such as locally funded medical care for accident victims, parking facility costs, air pollution control efforts, and planning activities.

Estimates:

- Stanley Hart estimated that Pasadena automobile subsidies equal about $270 annually per household or $0.013 per vehicle mile. When roadway construction and maintenance expenditures are subtracted out to avoid double counting costs in Chapter 3.6, the remaining shares of law enforcement, emergency services, and public administration expenditures total $7.7 million, averaging about $0.008 per vehicle mile. In 1994 this is worth approximately $0.012 per mile.[3]

- Apogee Research estimated police, fire, and justice motor vehicle costs in Boston, MA and Portland, ME summarized in Table 3.8-1.[4]

Table 3.8-1 **Public Service Costs of Driving in Two Cities (¢ per vehicle mile)**

Boston	**Express-way**	**Non-Expwy**
High density	2.4	1.0
Medium density	1.1	0.4
Low density	1.1	0.5
Portland		
High density	1.3	0.5
Medium density	0.9	0.4
Low density	0.6	0.2

- The California Energy Commission estimates roadway service costs, including a share of law enforcement, safety, and administration at $0.012/mile for all vehicles.[5]

- Theodore Keeler et al. estimate the average cost of municipal automobile services (including police, fire, planning, court, public health, and power) at $0.012 per VMT.[6]

- Peter Miller and John Moffet estimate average municipal costs at $.0045 per VMT, with a higher value of $.01 in congested urban areas and $0.002 for rural travel.[7]

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[2] Daniel Ridgeway, "An Assessment of the Cost of Private Motor-Vehicle Use to the City and County of Denver," self published graduate studies paper, Denver, March 1990.
[3] Stanley Hart, "An Assessment of the Municipal Costs of Automobile Use," 1985, p.14.
[4] *The Costs of Transportation: Final Report*, Conservation Law Foundation (Boston), 1994, p. 138-144.
[5] *1993-1994 California Transportation Energy Analysis Report*, CEC (Sacramento), Feb. 1994, p. 29.
[6] *The Full Costs of Urban Transport*, Institute of Urban and Regional Development (Berkeley), Monograph #21, 1975, p. 51.
[7] *The Price of Mobility*, National Resource Defense Council (Washington DC), Oct. 1993, p.15

- Fadi Nassar and Fazil Najafi estimate that law enforcement and risk management costs average about $5,000 annually per lane mile, and two to three times that in urban areas.[8] If an average lane carries 7,500 vehicles per day, this cost averages $0.002 to $0.005 per VMT.

- The Office of Technology Assessment study indicates average externalities of $0.007 to $0.04 per vehicle mile based on the following costs (billions):[9]

	Low Cost	High Cost
Police protection	$7.9	$76.5
Fire protection	1.4	3.2
Court and judicial system	4.0	10.0
Corrections	2.5	3.5
Government pollution control	1.0	3.0
Totals	$16.8	$96.2

- Daniel Ridgeway estimates municipal automobile subsidies exceed $.003 per VMT.[10]

- Ken Small describes a study that estimates automobile municipal service costs in San Francisco average 2.8¢ per motor vehicle mile.[11]

- Transport 2021 estimates "protective services" of traffic law enforcement and emergency services (based on 10% of police and 5% of fire department costs) at $0.004 Canadian per vehicle kilometer, or about $0.005 U.S. per vehicle mile.[12]

Variability: Miller and Moffet indicate that service costs are significantly greater per mile in congested urban areas than for rural driving. This is supported by Nassar and Najafi's estimates of police patrol costs.

Conclusions: Several estimates indicate that municipal services not funded by vehicle user fees average more than $0.01 per mile, with higher costs in urban areas. Urban Peak travel is estimated to incur municipal service costs of $0.015 per mile, Urban Off-Peak $0.01 per

[8] Fadi Emil Nassar and Fazil Najafi, "Quick Approach to Estimate Law Enforcement Cost on Urban Roads," *Transportation Research Record #1262*, 1989. p. 39-47.
[9] *Saving Energy in U.S. Transportation*, U.S. Office of Technology Assessment, 1994, p. 104-108.
[10] "An Assessment of the Cost of Private Motor-Vehicle Use to the City and County of Denver," 1990.
[11] Ken Small, *Urban Transportation Economics*, Harwood (Chur), 1992, p. 82.
[12] *Cost of Transporting People in the British Columbia Lower Mainland*, Greater Vancouver Regional District (Vancouver), 1993, p. 29.

mile, and Rural travel $0.005. This cost is applied equally to all motor vehicles. Rideshare passengers are estimated to incur no additional municipal service costs. Bicycling, walking, and telecommuting are estimated to cost 10% as much per mile as an automobile.

Best Guess **Municipal Service Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.015	0.010	0.005	0.009
Fuel Efficient Car	0.015	0.010	0.005	0.009
Electric Vehicles	0.015	0.010	0.005	0.009
Van	0.015	0.010	0.005	0.009
Rideshare Passenger	0.00	0.00	0.00	0.00
Diesel Bus	0.015	0.010	0.005	0.009
Electric Bus/Trolley	0.015	0.010	0.005	0.009
Motorcycle	0.015	0.010	0.005	0.009
Bicycle	0.002	0.001	0.00	0.001
Walk	0.002	0.001	0.00	0.001
Telecommute	0.002	0.001	0.00	0.001

Automobile Cost Range: Based on estimates cited:

Minimum	Maximum
$0.003	$0.015

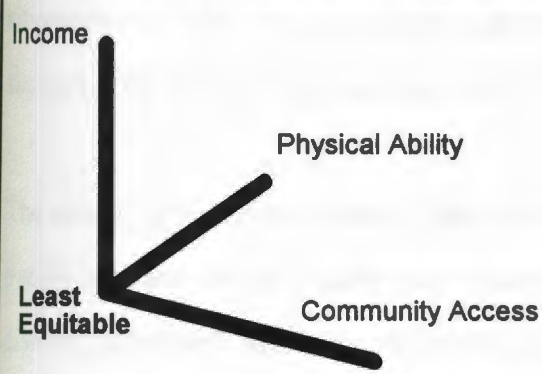
3.9 Transportation Equity and Option Value

Definitions: *Transportation Equity:* Adequate transportation for people who are economically, socially, or physically disadvantaged.[1] *Transportation Option Value:* The value of having a variety of transport choices.

Description: Transportation equity and option value are based on the quality and quantity of access, especially for people who are already socially disadvantaged because they are poor or disabled. They are affected by the transport system, land use patterns, facility design, and social habits that affect travel requirements, and the quality of public transit, trains, ride sharing, bicycling, walking, and special mobility services.

Discussion: Since access to goods, services, jobs and other destinations is important for economic, personal and social activities, inadequate mobility and access impose a variety of costs on individuals and society. These costs are social in nature because they are affected by social decisions and policies, such as transportation investments, zoning codes, and the location of public services, and because many of the costs are ultimately borne by society in terms of reduced productivity and general inequity.

Figure 3.9-1 **Transportation Equity**



There are three dimensions to transportation quality: income, physical ability and community access. Community access is defined as the ease with which people can access goods, services, and destinations in their community. Low income, physical disability and poor community access contribute to transportation disadvantage. Improvement in one factor partially compensates for low levels in another.

[1] Transportation equity is explored further in Chapter 7.

Transportation prices, transit subsidies, special mobility services, and handicapped access have been the focus of most discussions of transportation equity and option value, but other factors such as urban form, social habits, and personal security are also important. Being transportation disadvantaged is affected not only by a person's physical and financial abilities, but also on how much travel is required to access goods and services, and what travel choices are available in their community. Most North American communities now have a high level of automobile dependency.[2] A "personal" car is required to participate in most activities and there are few travel alternatives. This imposes two sets of costs. The first are impacts on people regardless of their wealth or physical ability. Even those who own and drive a personal car suffer from a lack of alternatives. For example:

- Households must own extra cars to guarantee that one is available for every trip, or rely on expensive alternatives such as car rentals and taxies.
- Household members who are too young or too old to drive, and out of town guests must be chauffeured to all destinations.
- Irresponsible drivers who commit multiple traffic offenses are still allowed a drivers license because of the tremendous social cost of not driving.
- Drivers are immobilized when their car breaks down or is unavailable for any reason.

Economists use the term *option value* to describe the benefit of maintaining an option that is not immediately used.[3] The concept of option value has been applied in a variety of situations including transport policy analysis to explain why people are often willing to support programs and facilities they seldom or never directly use.

The second set of costs of automobile dependency are the extra burdens imposed on people who are already socially, economically, or physically disadvantaged. The poor, disabled and elderly are further disadvantaged by a lack of access to public services,

[2] Peter Newman and Jeff Kenworthy, *Cities and Automobile Dependency*, Grover (Aldershot), 1989).
[3] Johansson, *The Economic Theory and Measurement of Environmental Benefits*, 1987, p. 5

employment, and social activities. This reduces social equity, defined as increased discrepancy between advantaged and disadvantaged people. Since policy makers and planners are generally drivers and car owners, non-drivers' needs are underrepresented in public decision making.[4] As use of public transit, bicycling, and walking has reduced and users are increasingly from disadvantaged populations, these modes become stigmatized, to the point that a U.S. transit system executive has stated, "*Show me a man over thirty who regularly takes the bus, and I will show you a life failure.*"[5] Residential, employment, commercial, and municipal services are increasingly located for optimum parking and proximity to freeways, with poor access for nondrivers.[6] Elmer Johnson states,

> *"[T]he dominance of the automobile has reduced the availability of public transportation. For those too young, too old, too poor or too infirm to drive, the paucity of mobility alternatives severely limits their opportunity for education and their ability to share in other essential everyday activities. Moreover, as more employers have moved to the suburbs, more jobs require car mobility."*[7]

Poverty and being transportation disadvantaged are closely linked. According to the 1990 National Personal Transportation Survey only 9% of U.S. households were without an automobile, but of those 42% were below the poverty level in income.[8] Rural residents are especially impacted.[9] As described by Meyer and Gomez-Ibanez:

> *"It is widely believed that poor, handicapped, and elderly persons who cannot use an automobile and do not have access to high-quality, low cost public transportation cannot participate fully in society--especially given the dispersal of residences, workplaces, and shopping and recreational centers in U.S. metropolitan areas."*[10]

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[4] James Kunssler, *The Geography of Nowhere*, Simon and Schuster, 1993.
[5] Joel Garreau, *Edge City*, Doubleday (NY), 1991, p. 130.
[6] The exceptions are residents of a few large cities such as New York and Philadelphia where transportation is relatively diverse and wealthy non-drivers who can afford unlimited chauffeuring.
[7] Elmer Johnson, *Avoiding the Collision of Cities and Cars*, American Academy of Arts and Sciences (Chicago), 1993, p 8.
[8] Charles Lave & Richard Crepeau, "Travel by Households Without Vehicles, *1990 NPTS Travel Mode Special Report*, p. 29
[9] Stephen Nutley in *Modern Transport Geography*, Hoyle and Knowles, ed., Belhaven Press (London), 1992, chapter 8.
[10] John Meyer & Jose Gomez-Ibanez, *Autos, Transit and Cities*, 1981, Twentieth Century Fund, p. 230

Altshuler adds:

"It is unusual to come across a situation in which circumstances of the disadvantaged have deteriorated absolutely over a sustained period of time. For many Americans without cars and/or drivers' license, however, the absolute level of mobility has fallen sharply over the past several decades. Given the dramatic mobility improvements experienced by most Americans in this same period, it follows that the relative deprivation of those left behind has worsened acutely."[11]

Hillman examines the equity impacts of increased automobile dependency on children:

"In the pursuit of adult mobility, and of the impacts on children of its growth have been overlooked...the motor vehicle has totally colonized the most convenient local places in which children could play and socialize. Most importantly, there is the issue of road accidents—the most frequent cause of accidental mortality among children."[12]

Automobile dependency and use impose special hardships on the poorest households. According to Peter Freund and George Martin these include:[13]

- Poor families spent twice the proportion of income on automobiles as wealthy families.
- A lack of transportation by inner city residents to the growing portion of jobs in suburbs is a contributing factor to unemployment and poverty.
- The poor suffer higher than average automobile air pollution and accident risk impacts.

Some analysis of transportation disadvantaged people focus on the problems of households that own no motor vehicles.[14] However, owning a car does not necessarily eliminate mobility problems. Many individuals in households with cars still experience significant problems accessing services, jobs and other destinations. Merle Mitchell describes concern among social policy analysts about "locational disadvantage" associated with people who live in rural areas or outer suburbs that have poor access to community

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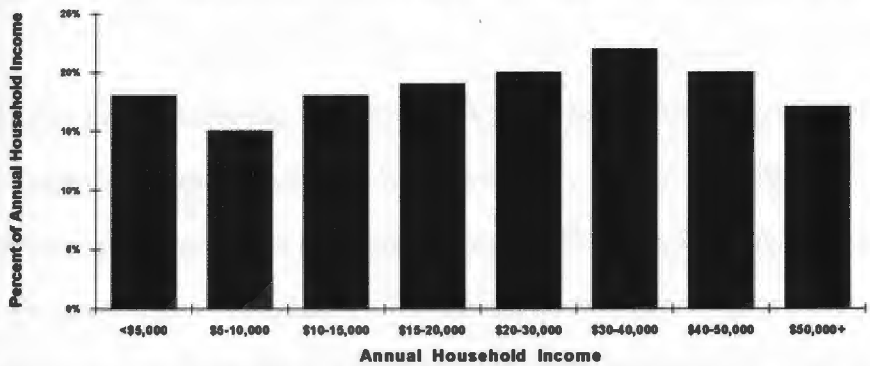
[11] Alan Altshuler, *The Urban Transportation System,* 1979, MIT Press (Cambridge), p. 253
[12] Mayer Hillman, "Foul Play for Children: A Price of Mobility," *Town and Country Planning*, Oct. 1988, pp. 331-332.
[13] Peter Freund and George Martin, *The Ecology of the Automobile*, Black Rose (NY), 1993, p. 46-49.
[14] For example, see Charles Lave and Richard Crepeau, "Travel by Households Without Vehicles" in the *1990 Nationwide Personal Transportation Survey, Travel; Travel Mode Special Report*, USDOT, 1994.

services, although many have a household automobile.[15] The requirement to own motor vehicles can be a serious financial burden on the poorest households, as indicated by Figure 3.9-2. The portion of households that are likely to have special needs (the elderly, the poor, and single parents) are growing demographically, as are automobile dependent transport and land use patterns, so these problems may increase.[16]

Figure 3.9-2 **Automobile Expenditures as Percentage of Household Income**[17]



Automobile expenditures decline with income among middle class families, but are higher for the lowest income class, indicating that automobile dependency places a burden on the poorest households.

When 1,600 randomly selected New Mexico residents were asked, "*Do you believe that the ability to get where you want ot go in a reasonable time and for a reasonable cost is or should be a basic right in the same sense as freedom of speech or the pursuit of happiness?*", 63.8% of responses said yes, 22.7% said no, and 13.5% were uncertain.[18]

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[15] Merle Mitchell, "Links Between Transport Policy and Social Policy" in *Transport Policies for the New Millennium*, Ogden et al. editors, Monash University (Clayton), 1994.
[16] Susan Hanson, *The Geography of Urban Transportation*, Guilford Press (NY), 1986, p.7.
[17] U.S. Department of Labor, *Consumer Expenditure Survey, 1989* (Washington DC), 1990. Although driving and fuel consumption decline for the lowest income households, as discussed in Section 5.3, costs do not appear to decline in proportion. The likely explanation is that there is a minimal level of fixed automobile ownership costs, including registration, insurance and repair costs that cannot be avoided.
[18] John Hamburg, Larry Blair and David Albright, *Mobility as a Right*, Transportation Research Board 1995 Annual Meeting (Washington DC), paper #951001.

The existence and public concern over transportation inequity are indicated by strong public support for public transit, special mobility services, and handicap access. Much of the political and economic support for transit comes from people who seldom or never use it themselves. About 64% of U.S. transit service fiscal costs are directly subsidized, totaling about $10 billion in 1991.[19] Transit also receives indirect subsidies, including tax exemptions, and facilities (bus stops, pull-outs, and road maintenance costs) provided by other budgets.

Economist Jim Lazar comments, "*...transit is the most oversubsidized public service in the state* [Washington]*; and it needs to be, in order to compete with the most oversubsidized private service in the state (i.e. cars).*"[20] Similarly, Elmer Johnson states, "*The case for government subsidization* [of transit] *rests primarily on equity considerations: on the ground that a base level of urban accessibility is a primary good (i.e., one that is instrumental to the pursuit of diverse ends) that should be provided to the less advantaged at below cost.*"[21]

Robert Cervero identifies mobility for the carless and poor, and transportation option value in general, as the primary benefits of transit service in the United States.[22] He concludes that environmental, energy, economic development and congestion relief benefits are minor except in large cities.[23] Of 5,085 transit and special mobility services in the U.S., only 787 are large urban transit systems, 1,077 are small urban or rural transit

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[19] *1992 Transit Fact Book*, American Public Transit Association (Washington DC) p.45.
[20] Jim Lazar, private communications, January 1994.
[21] *Avoiding the Collision of Cities and Cars*, American Academy of Arts and Sciences, 1993, p. 34.
[22] Robert Cervero, "Perceptions of Who Benefits From Public Transit," *TRR*, #936, 1982, pp. 15-19.
[23] Some transit services, such as suburban oriented commuter rail, may provide little equity benefit, and are justified primarily for avoiding congestion at large employment centers. See David Hodge, Social Impacts of Urban Transportation Decisions: Equity Issues, *The Geography of Urban Transportation* (Susan Hanson Ed.), Guilford Press, 1986.

systems, and 3,222 are non-profit elderly and disabled service providers.[24] These smaller systems also tend to have the highest percentage of public subsidies per rider mile. These subsidies demonstrate the importance of transport equity and option value.

Even with these subsidies, transit and special mobility services only partially compensate for the discrepancy between drivers and non-drivers. In most communities transit service is infrequent, limited in time and location, sometimes uncomfortable, and carries a social stigma. Bus and train service between cities is even worse, often taking several times as long and costing much more than driving. Thus, the unmet demand for transport equity and option value is greater than what is reflected in transit subsidies. In other words, current subsidies for public transportation services at its existing quality imply that society would be willing to pay even more for significantly better non-automotive transportation.

Is this a cost of driving? Applying a with-and-without test, one can ask: "*If automobile use decreased, would the quality and choice of non-automotive transport improve, with benefits to disadvantaged people?*" Studies indicate that provisions for automobiles (per capita road and parking space) and per capita annual mileage are inversely correlated to transit service quality and the use of non-automotive travel.[25] If current drivers switched to other travel modes such as transit, ride sharing, bicycling, and walking, the increased demand would probably improve the quantity and quality of transport available to non-drivers due to economies of scale and increased political support.

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[24] *1992 Transit Fact Book*, American Public Transit Association (Washington DC), pp. 16-23.
[25] Peter Newman and Jeff Kenworthy, *Cities and Automobile Dependency*, Gower Press, 1989, p.38, 54.

Comedy Becomes Tragedy

A city slicker driving a fancy car pulls up to an old farmer along a Maine back road.

"How do I get to Muggsville?" asks the out-of-town driver.

The farmer ponders for a moment then answers, *" 'Fraid you can't get there from here."*

A small joke, but consider a minor variation: The same question is asked by a bus rider, bicyclist or pedestrian, and the same answer given. Comedy becomes tragedy because in practice non-drivers frequently cannot get where they want to go, at least with any degree of ease, safety and economy. Bicycling and walking on many roadways is unsafe or even illegal. Many small communities have no public transportation service, or the service is irregular and slow. Intercity bus and train service typically take twice as long as driving a private car and costs several times as much in out-of-pocket expenses.

These are not necessary conditions of a modern transportation system. Many countries have transportation and land use patterns that provide more travel choices, and much better transportation services for non-drivers. The extreme degree of automobile dependency in most North American communities results from public policies that were motivated by political manipulation as much as economic efficiency or other social goals.[26] The U.S. Congress recognized the problems caused by automobile dependency in the Intermodal Surface Transportation Efficiency Act, which is based on the premise that developing in a wider range of travel modes, including walking, bicycling, buses and rail transit, will increase the efficiency and equity of the U.S. transportation system.

[26] Stephen Goddard, *Getting There*, Basic Books (NY), 1994.

Estimates: Although there are many indications that this cost exists, no quantified estimates have been found. One approach for measuring these costs is based on current U.S. financial transit subsidies, which total approximately $10 billion annually. Assuming:

1. Indirect subsidies including tax exemptions, special facilities such as bus pullouts, and road wear equal 10% of financial subsidies.
2. Two thirds of transit subsidies are justified on the basis of transportation equity and option value (to put this another way, society would maintain 2/3 of current subsidies if equity and option value where the only benefits transit provided.)
3. Transit only captures 1/2 of all transportation equity and option value demand (in other words, society would be willing to double existing subsidies if transit provided the same quality of service as personal automobiles).
4. Driving is 75% responsible for the current lack of transport equity and option value.

Results: Automobiles' share of reduced transport equity and option value = $10 billion x 1.1 x 0.66 x 2 x 0.75 = $10 billion / 2,300 billion annual miles = $0.005 / vehicle mile.

Because so little research is available to help quantify this cost, this estimate is extremely uncertain. The high cost per trip of special mobility services that are justified specifically for equity value, and survey results described later in Section 4.5 indicate that this estimate of equity and option value may significantly understate the true cost.

Variability: This cost is greatest in communities with the greatest degree of automobile dependency in terms of land use, transportation options, and social patterns. Although transit and special mobility services receive the greatest attention as ways to improve transport equity and option value, other modes, including ride sharing, bicycling, and walking may be equally important in many circumstances. Transit systems that are oriented toward upper-income commuters may provide little or no equity value. Telecommuting can provide transport equity and option benefits, although it has sometimes been criticized by labor organizations as a threat to job equity if it is required by employers.

Conclusions: Although transportation equity and option value can be demonstrated both theoretically and empirically to have value, and a lack of these attributes incurs various costs, there are currently no models that measure them or determine how much automobile use is responsible.[27] The estimate developed above based on transit subsidies is probably low but will be used until better methods are developed. It is applied to private vehicles, but not to van pools, bus, trolley, bicycle, walk or telecommute, which are viable alternatives for non-drivers.

Best Guess **Equity and Option Value Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.005	0.005	0.005	0.005
Fuel Efficient Car	0.005	0.005	0.005	0.005
Electric Vehicles	0.005	0.005	0.005	0.005
Van	0.005	0.005	0.005	0.005
Rideshare Passenger	0.00	0.00	0.00	0.00
Diesel Bus	0.00	0.00	0.00	0.00
Electric Bus/Trolley	0.00	0.00	0.00	0.00
Motorcycle	0.005	0.005	0.005	0.005
Bicycle	0.00	0.00	0.00	0.00
Walk	0.00	0.00	0.00	0.00
Telecommute	0.00	0.00	0.00	0.00

Automobile Cost Range: Due to the uncertainty of this cost, its minimal value is zero and the maximum is somewhat arbitrarily set at an order of magnitude larger than the estimate developed above.

Minimum	Maximum
$0.00	$0.05

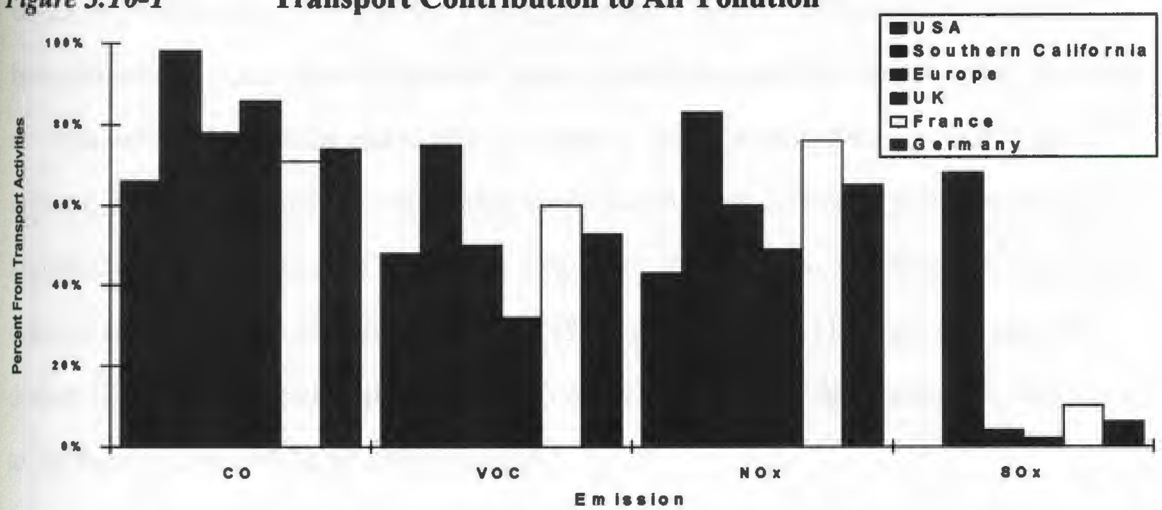
[27] For additional evidence of the existence of transportation and equity values see survey results discussed in Section 4.5.

3.10 Air Pollution Costs

Definition: Costs of air pollution caused by motor vehicle use.

Description: Motor vehicles produce a number of air pollutants, including carbon monoxide (CO), particulates (PM), nitrogen oxides (NOx), volatile organic compound (VOCs, also called hydrocarbons, or HC and reactive organic compounds or ROG), sulfur oxides (SOx), carbon dioxide (CO_2), methane (CH_4), road dust, and toxic gases such as benzene. These have a variety of negative effects including human illness, disability and deaths, crop and material damage, global warming, ozone depletion, acid rain, reduced visibility, and increased cleaning costs. Motor vehicle's share of some major pollutants is shown in figures 3.10-1 and 3.10-2.

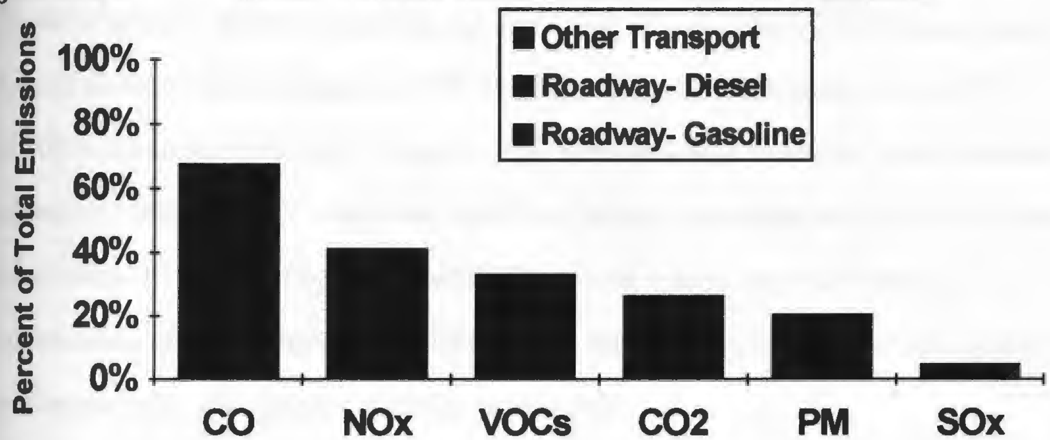
Figure 3.10-1 **Transport Contribution to Air Pollution**[1]



Transport activities are the largest overall source of many harmful emissions, especially in urban areas where they impose the greatest cost due to population density.

[1] Ken Small and Camilla Kazimi, "On the Costs of Air Pollution from Motor Vehicles," *Journal of Transport Economics and Policy*, January 1995, Table 1.

Figure 3.10-2 **Motor Vehicles Contribution to U.S. Air Pollution**[2]



Transportation, especially roadway travel, is a major contributor to air emissions. These percentages are higher in urban areas where pollution problems are greatest.

Discussion: Air pollution is one of the most often cited external costs of motor vehicle use. Estimating this cost requires information about the relationships between driving, emissions, distribution, and impacts. Pricing this cost requires placing dollar values on human mortality, morbidity, discomfort, loss of recreation, aesthetic degradation, damages to crops, wildlife, materials and increased cleaning. Many studies focus on human health impacts, but research indicates that other air pollution costs, including global warming and aesthetic damage may also be significant. One study, for example, estimated U.S. aesthetic costs of smog to be $7.9 billion annually in 1982, worth about $11.5 billion in current dollars ($0.005 per vehicle mile).[3] Some estimates of global warming rank CO_2 emissions as the highest automobile air pollution cost.[4]

Increasingly sophisticated vehicle engine controls and fuel changes mandated by state and federal laws have reduced running tailpipe emissions for hydrocarbons by 91%, CO by 96%, and NOx by 85% since 1970.[5] The 1990 U.S. Clean Air Act Amendment requires

[2] Homburger, Kell and Perkins, *Fundamentals of Traffic Engineering, 13th Edition*, Institute of Transportation Studies, UCB (Berkeley), 1992, p. 30-3, 32-1.
[3] Robert Crandall, et al, *Regulating the Automobile*, Brookings Institute (Washington DC), 1986.
[4] William Cline, *The Economics of Global Warming*, Institute of International Economics, 1992.
[5] Jon Kessler and William Schroeer, *Meeting Mobility and Air Quality Goals*, USEPA, Oct. 1993

additional emission reductions through the year 2004. These include a 63% reduction in NOx from diesel trucks and buses, a 84% reduction in truck particulates, and a 92% reduction in urban bus particulates starting with 1994 models.[6] However, since catalytic converters are only effective when hot, significant tailpipe emissions still occur during the first few miles (±5 miles) of operation while the vehicle warms up, and "hot-soak" emissions occur after the engine stops.[7] Emissions also occur while vehicles sit unused (diurnal emissions), and during petroleum processing.

Several approaches are used to calculate air emission unit costs. Some estimates are based on damage costs.[8] Others use control costs, based either on the cost of emission control equipment or the price needed to reduce emissions to an established goal, such as by charging an emission tax.[9] The cost of growing forests to sequester carbon is sometimes used to estimate CO_2 costs, but that approach is inappropriate for large scale policy analysis due to limits of total potential reforestation. Table 3.10-1 shows air emission unit values used by several researchers and organizations.

Table 3.10-1 **Air Pollution Monetization Values ($1993 per kilogram)**

Source	CO_2	PM_{10}	NOx	SOx	VOC
CA Energy Commission, in state	0.01	9.79	14.56	14.44	4.14
CA Energy Commission, outside state	0.01	1.00	1.50	1.50	0.38
KPMG, B.C. Lower Mainland	NA	4.27	3.20	7.93	2.93
MA Dept. of Public Utilities	0.024	4.40	7.15	1.65	5.83
Miller and Moffet	0.06 to 0.13	3.60	0.64	1.00	3.60-7.20
Pace University	0.02 to 0.058	2.08	2.06	5.09	NA
Greene and Duleep	0.011 to 0.11	NA	2.20	NA	3.68
Average	0.046	3.97	4.89	5.15	2.43

This table shows air emission unit costs developed by various agencies and researchers.

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[6] John Schiavone, *Retrofit of Buses to Meet Clean Air Regulations*, Synthesis of Transit Practice 8, TRB, National Academy Press (Washington DC), 1994.

[7] Homburger, Kell and Perkins, *Fundamentals of Traffic Engineering, 13th Edition*, Institute of Transportation Studies, UCB (Berkeley), 1992, p. 30-10..

[8] William Nordhaus, "Economic Policy in the Face of Global Warming" *Energy and the Environment in the 21st Century*, MIT Press (Cambridge), 1990; William Cline, *Economics of Global Warming*, Institute of International Economics, 1992

[9] For example see Per Kågeson, *Getting the Prices Right*, European Federation for Transport & Environment (Bruxelles), 1993, p. 68-70.

Estimates:

- Apogee Research estimated air pollution costs in Boston, MA and Portland, ME for peak and off-peak travel at high, medium and low densities, shown in Table 3.10-2.

Table 3.10-2 **Air Pollution Costs in Two Cities (¢ per passenger mile)**[10]

	Expwy		Non-Expwy		Comm. Rail		Rail Transit		Bus	
Boston	Peak	Off-P	Peak	Off-P	Peak	Off-P	Peak	Off-P	Peak	Off-P
High	7.9	6.6	10.6	8.9	0.9	2.2	<0.2	<0.2	0.8	4.4
Medium	6.6	9.5	7.9	7.3	1.0	2.5	<0.2	<0.2	2.4	5.8
Low	7	9.5	7.3	6.9	2.0	4.9	n/a	n/a	2.4	5.5
Portland										
High	6.5	6.9	7.9	7.3	n/a	n/a	n/a	n/a	5.2	4.7
Medium	6.6	7.0	7.3	6.9	n/a	n/a	n/a	n/a	5.2	4.6
Low	12.1	12.1	6.6	6.6	n/a	n/a	n/a	n/a	11.0	11.0

- Robert Ayres and Jorg Walter estimate market damage costs of global warming at $30 to $35/ton of CO_2 equivalent, plus significant non-market environmental damages.[11]

- The California Energy Commission estimates air pollution costs in that state to average $0.012 to $0.014 per vehicle mile, based on 1992 CEC values for NOx, SOx, ROGs, PM_{10} and CO.[12] In addition, they apply a climate change charge of $0.0042 ($0.084/gallon of gasoline), based on $28/ton of carbon released.

- Michael Cameron cites the report *Exhausting Clean Air: Major Issues in Managing Air Quality*,[13] which estimates total Southern California air pollution costs at $7.4 billion annually, for an average cost of driving in the region at $.06 per VMT.[14]

- James Cannon concludes that total U.S. automobile emission costs are approximately $50 billion annually; averaging $.025 per vehicle mile.[15]

- William Cline estimates damage costs for a 2.5°C average temperature increase by 2050 at 1% of U.S. GDP, which he doubled to account for non-market cost impacts.[16] He estimated that a 10°C average temperature rise by 2100 would cost of 6% of GDP, and up to 20% if non-market goods are included.

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[10] Apogee Research, *The Costs of Transportation*, Conservation Law Foundation (Boston), 1994, p. 148.
[11] Robert Ayres and Jorg Walter, "The Greenhouse Effect: Damages, Costs and Abatement," *Environmental and Resource Economics*, Vol. 1, 1991, p. 237-270.
[12] *1993-1994 California Transportation Energy Analysis Report*, California Energy Commission (Sacramento), Feb. 1994, p. 29.
[13] California Assembly Office of Research *Exhausting Clean Air*, 1989.
[14] Michael Cameron, *Transportation Efficiency*, 3/91, Environmental Defense Fund (Oakland), p.21.
[15] *Los Angeles Times*, Jan. 20, 1990, p. A18, based on "The Health Costs of Air Pollution; A Survey of Studies Published 1984-1989", for the American Lung Association.
[16] William Cline, *Economics of Global Warming*, Institute of International Economics, 1992.

- Convergence Research reviewed air emission unit costs used by 37 regulatory and research sources.[17] Table 10-3 summarizes this data.

Table 10-3 **Air Emission Unit Values From 37 Regulatory and Research Sources**

(1990 US Dollars/Ton)	CH_4	CO	CO_2	H_2S	N_2O	NOx	SOx	TSP	VOC/ROG
Minimum	$100	$500	$2	$1,800	$3,700	$42	$405	$167	$340
Maximum	$740	$1,000	$84	$1,800	$4,158	$40,000	$21,185	$8,780	$21,175
Average Value	$326	$842	$25	$1,800	$3,880	$8,212	$4,011	$3,401	$5,986
Median Value	$375	$907	$20	$1,800	$3,700	$4,209	$1,793	$2,496	$3,300
Count	9	6	26	1	5	36	34	20	15

- DeLuchi, Sperling and Johnson estimate total annual U.S. human health costs from motor vehicles range from $5 -$150 billion (1993 dollars), averaging $0.002 to $0.068 per vehicle mile.[18]

- The Greater Vancouver Regional District estimates the emission rate per passenger for various modes under average and peak urban conditions, shown in Table 3.10-4.

Table 3.10-4 **Emission Rates for Selected Modes (grams per passenger-mile)**[19]

Mode	Passengers	HC	CO	NOx	SOx	PM
Average						
Automobile	1.0	3.15	23.57	1.91	0.07	0.10
Car Pool	2.4	1.31	9.82	0.80	0.03	0.04
Van Pool	5.0	0.72	5.42	0.44	0.02	0.02
Diesel Bus	20	0.11	1.50	0.67	0.09	0.17
Articulated Diesel	23	0.12	1.67	0.74	0.10	0.19
Methanol Bus	20	0.01	0.02	0.49	0.00	0.00
Trolley Coach*	20	0.00	0.001	0.006	0.00	0.00
Articulated Trolley*	32	0.00	0.001	0.007	0.10	0.00
Rail Transit*	25	0.00	0.001	0.006	0.00	0.00
Rush Hour						
Automobile	1.3	2.42	18.13	1.47	0.05	0.08
Car Pool	3.6	0.88	6.55	0.53	0.02	0.03
Van Pool	7.2	0.50	3.77	0.31	0.01	0.02
Diesel Bus	37	0.06	0.81	0.36	0.05	0.09
Articulated Diesel	44	0.06	0.87	0.39	0.05	0.10
Methanol Bus	37	0.01	0.10	0.27	0.00	0.00
Trolley Coach*	37	0.00	0.001	0.003	0.00	0.00
Articulated Trolley*	44	0.00	0.001	0.004	0.00	0.00
Rail Transit*	53	0.00	0.001	0.003	0.00	0.00

* *Electric Vehicles*

- Per Kågsen estimates that NOx, VOC, and SO_2 costs in Europe average $0.03 per automobile passenger mile (14.6 ECU/1,000 km).[20]

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[17] Kevin Bell, *Valuing Emissions from Hermiston Generating Project,* Convergence Res. (Seattle), 1994.
[18] *Comparative Analysis of Future Transportation Fuels*, UCB (Berkeley), 1987.
[19] *GVRD Air Quality Management Plan: Stage 2 Draft Report: Priority Emission Reduction Measures*, Greater Vancouver Regional District (Vancouver), May 1992, Table 5-8, p.5-43.

- Keeler provides a range of pollution impact values based on human health impacts ranging from $.0024-.059 depending on vehicle age, with an average of $.014.[21]

- James MacKenzie et al. estimate motor vehicle air pollution costs to be at least $10 billion, or about $0.005 per motor vehicle mile, and global warming costs at $60 per ton of CO_2 equivalent ($0.012 per mile) based on control costs.[22]

- Air pollution unit cost estimates by Peter Miller and John Moffet for automobile emissions under urban and rural conditions are shown in Table 3.10-5.[23]

Table 3.10-5 **Urban and Rural Air Pollution Costs ($/kg)**

	CO_2	HC	CO	NOx	TSP	SO_2
Urban	0.06-0.13	7.20	12	0.60-8.40	0.08-0.013	0.01-0.36
Rural	0.06-0.13	3.60	0	0.05-0.06	0	0.0003

- The Office of Technology Assessment study estimates U.S. annual automobile air pollution costs (including human health effects, global warming, agricultural losses, material, visibility and aesthetic losses) to range from $47 to $242 billion, for an external cost average of $0.02 to $0.10 per vehicle mile.[24]

- After reviewing various European studies Émile Quinet concludes that car transport is about 10 times more polluting than railways for passenger transport; and truck transport is about 10 times more polluting than rail per unit of freight transport.[25]

- Ken Small and Camilla Kazimi provide a comprehensive analysis of Southern California motor vehicle air pollution impacts.[26] For monetization they focus on human morbidity from particular and ozone, and human mortality from particulates. Based on a $4.87 million value of per statistical life and 1992 fleet mix they calculate average air pollution costs for gasoline cars of $0.033 per VMT, with a sensitivity analysis range of $0.014 to $0.12. These costs are expected to decline 50% by the year 2000 due to improved emission controls. Heavy duty diesel trucks are estimated to impose $0.53 per VMT, with a sensitivity range of $0.16 to $2.19. They state that road dust particulates may cost an additional $0.043 per VMT, and that global warming costs may add a comparable cost, but are not confident enough with these estimate to

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[20] Per Kågeson, *Getting the Prices Right*, European Fed. for Transport & Env. (Bruxelles), 1993, p. 82.
[21] Keeler, et al, *The Full Costs of Urban Transportation*, Institute of Urban and Regional Development (Berkeley), Monograph #21 (Berkeley), 1975, based on 1972 estimates.
[22] James MacKenzie, Roger Dower and Donald Chen, *The Going Rate: What it Really Costs to Drive*, World Resources Institute (Washington DC), 1992, p. 13.
[23] *The Price of Mobility*, Natural Resources Defense Council (Washington DC), Oct. 1993, p.45
[24] *Saving Energy in U.S. Transportation*, U.S. Office of Technology Assessment, 1994, p. 108.
[25] Émile Quinet, "The Social Costs of Transport: Evaluation and Links With Internalization Policies," in *Internalising the Social Costs of Transport*, OECD (Paris), 1994.
[26] Ken Small and Camilla Kazimi, "On the Costs of Air Pollution from Motor Vehicles," *Journal of Transport Economics and Policy*, January 1995, pp. 7-32.

include them. Professor Small has mentioned that emission in urban areas with better air circulation probably average about 1/3 of Southern California costs.[27]

- Sweden has established carbon taxes of $153/tonne for transport and residential fuels, and $38/tonne for industrial energy, to meet emission reduction goals.[28] Swedish authorities value NOx at $5.60 per kg. The European Federation for Transport and Environment applies the same value to hydrocarbon emissions for analysis purposes.[29]

- Transport Concepts estimates air pollution costs for freight as shown in Table 3.10-6.

***Table 3.10-6* Environmental Costs of Freight (1990 Vehicles)**[30]

	Net Payload	Load Factor	NOx	VOC	CO_2	Total
	Tonnes	Percent	Canadian Cents Per Tonne Km			
Semi-Truck	24.5	65%	0.28	0.061	0.38	0.72
B-Train Truck	44.2	65%	0.23	0.050	0.31	0.58
Truck Average						0.71
Piggyback	24.5	60%	0.20	0.010	0.15	0.36
Container	26.3	60%	0.16	0.008	0.12	0.29
Box Car	71.7	36%	0.14	0.007	0.11	0.25
Hopper Car	70	60%	0.08	0.004	0.06	0.15
Rail Average			0.13	0.007	0.10	0.23

- A Union of Concerned Scientists study compares lifetime emissions for new standard and ultra low emission vehicles (ULEV), and an electric vehicle, based on Southern California electrical generation mix, shown in Table 3.10-7.[31] About half of electrical generation emissions produced to power urban electric vehicles occur in urban air sheds, and about half occur in other regions where unit pollution costs are lower.

***Table 3.10-7* Lifetime Emissions For Gasoline and Electric Vehicles (kilograms)**

Pollutant	Average Gasoline	ULEV Gasoline	Electric
ROG	89-119	46-54	0.49
CO	531-1,072	198-478	2.76
NOx	110-121	60-66	24.28
PM_{10}	2.5	2.5	1.11
SOx	11.8	11.8	13.8
Carbon	19,200	19,200	5,509

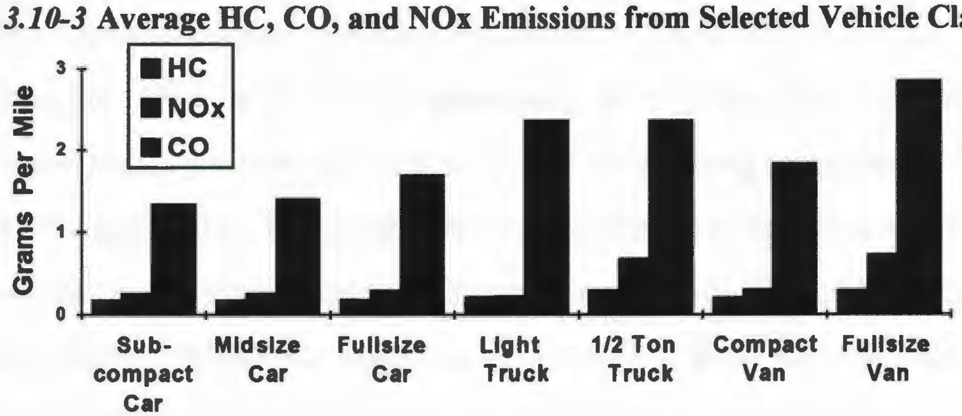
27 At FHWA Colloquium on the Social Costs of Transportation, Washington DC, 12 December 1994.
28 Per Kågeson, *Getting the Prices Right*, European Fed. for Transport & Env. (Bruxelles), 1993, p. 69.
29 Per Kågeson, *Environmental Car Guide 1994/95*, Eur. Fed. for Transport & Env. (Bruxelles), 1994.
30 *External Costs of Truck and Train*, Transport Concepts (Ottawa), October 1994, p.22.
31 Roland Hwang, et al., *Driving Out Pollution: The Benefits of Electric Vehicles*, UCS (Berkeley), 1994.

- USEPA tests show new motorcycles produce over double HC and CO, and higher NOx than automobile fleet averages, since they lack emission control equipment.[32]
- Wang and Santini estimate electric vehicles reduce CO and VOC emissions 98%, with smaller reductions in NOx and SOx, and 50% reductions in CO_2 emissions.[33]

Variability: Automobile air pollution costs vary tremendously depending on where and when it is used, the type and age of vehicle, the fuel that is used, and how it is driven. A significant portion of driving incurs minimal local air pollution costs, while emissions in polluted areas incur extremely high costs. Emissions that contribute toward global warming, ozone depletion, and acid rain have costs no matter where they occur.

Variation between common vehicle classes is shown in Figure 3.10-3. Older vehicles without catalytic converters and those that are not properly adjusted have much greater emissions per mile than average. These differences will be reduced somewhat in the next few years as older cars are retired and more areas implement inspection and maintenance programs. Catalytic converters are inefficient when cold, so emissions are much greater during the first few miles of a trip. Stop and go driving increases emissions per mile.

Figure 3.10-3 **Average HC, CO, and NOx Emissions from Selected Vehicle Classes**[34]



[32] *Compilation of Air Pollution Emission Factors; Vol.II*, USEPA, 1/91, tables 1.8.1, 1.8.4.
[33] Quanlu Wang and Danilo Santini, "Magnitude and Value of Electric Vehicle Emissions Reductions for Six Driving Cycles in Four U.S. Cities," *Transportation Research Record* 1416, 1993, p. 33-42.
[34] Gil McCoy, John Kim Lyons and Greg Ware, *A Low Emission Vehicle Procurement Approach for Washington State*, Washington State Energy Office, #92-071 (Olympia), June 1992, Table 5-2, p 32.

Conclusions: Air pollution costs are substantial. Pollution control equipment has reduced tailpipe emissions per VMT, but increased driving and residual emissions (especially from cold starts and evaporation) result in significant total costs. Estimates of average national local air pollution costs range from $0.01 to over $0.08 per VMT, depending on assumptions and data used. Some studies underestimate total costs because they include only human health impacts and ignore other costs. Adding global warming, acid rain, crop damage, ozone depletion, and aesthetic damage would increase these estimates.

For this analysis, Urban Peak local air pollution is estimated to cost $0.07 per VMT, which is slightly lower than Miller and Moffet's high estimate and slightly above Cameron's overall average estimate for Southern California. Urban Off-Peak costs are estimated at $0.05 per VMT, which represents the middle of the total range of estimates, and rural driving air pollution costs are estimated to be an order of magnitude lower at $0.005 per VMT, based on Miller and Moffet's values shown in Table 3.10-5. In addition, MacKenzie et al's estimate that greenhouse gases incur a $0.012 per mile cost is applied to all driving, equal to $60/t CO_2, representing the middle-high range of current cost estimates.

Using these values, average automobiles are estimated to impose a $0.082 per mile cost under Urban Peak ($0.07 local + $0.012 greenhouse), $0.062 under Urban Off-Peak ($0.05 local + $0.012 greenhouse), and $0.017 under Rural driving conditions ($0.005 local + $0.012 greenhouse). Energy efficient cars are estimated to have local emissions 10% lower than an average car, and half the global warming costs. Electric vehicles are estimated to produce 5% of local emission costs, and 50% of global warming costs.[35] Vans are estimated to produce 80% more air pollution than an average automobile.

[35] While there is less difference in cost per unit of emission between urban and rural driving for electric vehicles, (since generators are often located outside of urban areas), stop-and-go urban driving produces greater emissions per unit of travel, resulting in somewhat higher costs for urban driving.

Motorcycles are estimated to produce twice the local air pollution of a standard automobile, and half the greenhouse gas.

Rideshare passengers incur an air pollution cost 2% of a van based on a 20% emission increase for 10 passengers. In the past, buses produced local air pollution costs 10 to 15 times higher per vehicle mile than an automobile, due primarily to the high NOx and particulate output of diesel engines. This will decrease 75% or more in urban areas as strict 1995 emission control standards are implemented, so an estimate cost 2.5 times greater than an average automobile mile is used to represent current and near future local emissions, and greenhouse gas costs are 3 times higher based on fuel consumption. Electric trolleys and urban buses are estimated to have air pollution five times greater than an electric car. bicycling, walking, and telecommuting have no air pollution costs.

Best Guess **Air Pollution Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.082	0.062	0.017	0.048
Fuel Efficient Car	0.069	0.051	0.011	0.039
Electric Vehicles	0.010	0.009	0.006	0.008
Van	0.148	0.112	0.03	0.058
Rideshare Passenger	0.002	0.001	0.001	0.001
Diesel Bus	0.210	0.161	0.061	0.131
Electric Bus/Trolley	0.050	0.045	0.030	0.040
Motorcycle	0.146	0.106	0.016	0.078
Bicycle	0.00	0.00	0.00	0.00
Walk	0.00	0.00	0.00	0.00
Telecommute	0.00	0.00	0.00	0.00

To test these estimates, average automobile air pollution costs are multiplied by mileage:

	Annual Mileage (billion)	Estimate	Total (billion)
Urban Peak	460	$0.082	$37.7
Urban Off Peak	920	$0.062	$57.0
Rural	920	$0.017	$15.6
Total			$110.3

This total is within the range of many of the estimate described earlier. It represents a reasonable estimate of automobile air pollution costs, especially when all impacts (particulate, aesthetic, ozone depletion, emissions during petroleum processing, and global warming) are considered.

Automobile Cost Range: The minimum value estimate is based on the lower estimates described. The maximum is a combination of the highest local air pollution estimate plus the maximum estimate of carbon global warming costs.

Minimum	Maximum
$0.01	0.20

3.11 Noise

Definition: Unwanted sounds and vibrations produced by motor vehicle use.

Description: Motor vehicles cause a variety of noises and vibrations. Traffic noise includes engine acceleration, tire/road contact, braking, and horns. Vibration and infrasound (low frequency noise) are produced by heavy vehicles.

Measuring Noise

Noise is measured in *decibels* (dB), a logarithmic scale. A 10 dB increase represents a doubling in noise level. *Decibels A-weighted*, "dB(A)" units emphasize the frequency sensitivities of human hearing, and correlate well with subjective impressions of loudness. Common noise levels range from 30 to 90 dB(A).[1] Decibels are an instantaneous measurement, so various indexes are used to measure noise over a period of time:

- *Leq* represents the equivalent continuous sound level in dB(A) or a period over which the measurement is taken, usually 8 hours. Leq (8 hours) is used in many traffic noise standards established by OECD and WHO.
- L_{10} represents the noise level in dB(A) that is exceeded for 10 percent of the time over a one hour period. Analogous measurements, L_{01}, L_{05}, L_{50}, refer to noise levels exceeded 1, 5 and 50 % of the time over a one hour period. L_{10} *(18 hours)* is the mean of the hourly values taken over an 18 hour period, which, is typically from 6 a.m. to midnight. L_{10} is often used to define traffic noise in the U.S. and other countries.
- *MNL (Maximum Noise Level)* is the loudest noise during a certain period. This index is considered by some researches to correlate with noise annoyance better than Leq and L_{10}, but does not address the number of noise events, and is not widely used.

Discussion: According to an OECD report, "*Transport is by far the major source of noise, ahead of building or industry, with road traffic the chief offender.*"[2] Trucks, buses, and motorcycles are major contributors to traffic noise.[3] At low speeds most noise comes

[1] BTCE & EPA, "The Costing and Costs of Transport Externalities: A Review," *Victorian Transport Externalities Study*, Vol. 1, Environment Protection Authority (Melbourne, Australia), 1994.
[2] *Environmental Policies for Cities in the 1990s*, OECD (Paris), 1990, cited in Poldy, p.29.
[3] MacKenzie, Dower & Chen, *The Going Rate*, World Resources Institute (Washington DC), 1992, p. 21.

from vehicle engine and drivetrain, at higher speeds aerodynamic and tire/road noise dominate.[4] Overall traffic noise increases with speed, density, stops (which cause increased accelerations), and portion of large trucks and motorcycles.

Several studies show an average reduction in residential property values of about 0.5% for each unit change in Leq.[5] Various researchers have used these results to develop general property value depreciation indexes, some of which are shown in Table 3.11-1. The OECD recommends a noise depreciation index of 0.5% of property value per decibel increase if noise levels are above 50 dB(A) Leq (24 hours).[6] Douglass Lee estimates traffic noise costs at $21 annually per housing unit per decibel increase.[7]

Table 3.11-1 **Noise Depreciation Estimates**[8]

Country	**Percent House Price Reduction Per dB(A) Above 50 to 65 dB (A) Threshold**
France	0.4
Netherlands	0.5
Norway	0.4
Switzerland, Basle	1.26
Canada, Toronto	1.05
United States	0.15- 0.88
OECD	0.5

The number of residences impacted by traffic noise is significant in most developed countries. A.L. Brown and K.C. Lam estimate that approximately 25% of Australian urban dwellings are located on roads with over 2,000 vehicles per day and higher traffic speeds. Over 12% of dwellings in Australia directly front roadways carrying 8,000 or more vehicles per day. In addition, 8% of houses on low volume (<1,000 vehicles per day)

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4 Hornberger, Kell and Perkins, *Fundamentals of Traffic Engineering, 13th Edition*, Institute of Transportation Studies, UCB (Berkeley), 1992, p.31-3.
5 From Pearce and Markandya, *Environmental Policy Benefits: Monetary Valuation*, OECD (Paris), 1989.
6 M. Modra, *Cost-Benefit Analysis of the Application of Traffic Noise Insulation Measures to Existing Houses*, EPA (Melbourne), 1984, cited in Poldy, 1993.
7 Douglass Lee, "Efficient Highway User Charges," USDOT, as cited in MacKenzie.
8 Based on Weatherall 1988; Quinet 1990; and Steeting 1990 as cited in BTCE & EPA, "The Costing and Costs of Transport Externalities: A Review," *Victorian Transport Externalities Study*, Vol. 1, Environment Protection Authority (Melbourne), 1994.

are located close enough to a high traffic road to experience traffic noise exceeding 68 dB. Thus, approximately 1/3 of houses experience significant traffic noise.[9]

Table 3.11-2 **Selected Estimates of Total Transport Noise Costs**[10]

Country	Percent of GDP
Finland	0.3
France	0.24
Germany	0.20
Norway	0.23
United Kingdom	0.50
United States,	0.06 - 0.21
Japan	0.20
OECD, Average	0.15

Table 3.11-2 shows various estimates of total national transportation noise costs as a percentage of GDP. Some researchers suggest that property value depreciation due to noise is non-linear, and increases from 0.5 per dB(A) in the range of 50 to 60 dB(A), rising to 0.8 percent above 65 dB(A).[11]

Some researchers point out that hedonic pricing studies only measures a portion of total noise costs. It does not measure impacts on non-residential environments and ignores residual noise below a set standard, such as 50 dB. Erik Verhoef estimates that such estimates of traffic noise represent only 1/8th of the total cost[12] and Peter Bein interprets Sælensminde's research to imply that hedonic noise surveys identify only about 1/6th of total motor vehicle noise costs.[13] Since most of the estimates cited above are based on direct hedonic pricing, they are likely to significantly underestimate total noise costs.

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[9] A. L. Brown and K.C. Lam, "Can I Play on the Road, Mum? - Traffic and Homes in Urban Australia," *Road and Transport Research*, Vol. 3, No. 1, March 1994, p. 12-23.
[10] Based on Bouladon 1991 and Quinet 1990, as cited in BTCE & EPA, "The Costing and Costs of Transport Externalities: A Review," *Victorian Transport Externalities Study*, EPA (Melbourne), 1994.
[11] BTCE & EPA, "The Costing and Costs of Transport Externalities: A Review," *Victorian Transport Externalities Study*, Vol. 1, EPA (Melbourne), 1994, Table 3.4, based on Weatherall, 1988.
[12] Erik Verhoef, "External Effects and Social Costs of Road Transport," *Transportation Research*, Vol. 28A, 1994, p. 286.
[13] *Barnet Hastings Benefit Cost Analysis*, BC Ministry of Transportation and Highways (Victoria), 1994.

Estimates:

- Apogee Research estimated noise costs in Boston, MA and Portland, ME for several modes at high, medium and low densities. Totals are shown in Table 3.11-3.

Table 3.11-3 **Noise Costs in Two Cities (¢ per passenger mile)**[14]

	Expwy	Non-Expwy	Comm. Rail		Rail Transit		Bus	
Boston			Peak	Off-P	Peak	Off-P	Peak	Off-P
High	0.3	0.6	0.4	1.1	n/a	n/a	0.5	1.3
Medium	0.1	0.2	0.1	0.3	0.3	0.4	0.2	0.5
Low	<0.1	<0.1	0.1	0.1	n/a	n/a	<1.0	0.1
Portland								
High	0.2	0.5	n/a	n/a	n/a	n/a	1.1	1.0
Medium	0.1	0.1	n/a	n/a	n/a	n/a	0.2	0.2
Low	<0.1	<0.1	n/a	n/a	n/a	n/a	0.1	0.1

- Per Kågeson estimates motor vehicle noise costs in Europe at $0.006 per passenger mile (3.0 ECU/1,000 km).[15]

- Theodore Keeler et al. estimate the marginal noise cost of an added freeway vehicle mile at $.001-2 in 1975 ($.002-4 current dollars), but offer no estimate for impacts on local streets, which they state would be considerably higher.[16]

- Brian Ketcham estimates average U.S. automobile noise costs at $.001 per vehicle mile, and noise costs for heavy vehicles average $.04 mile. He also estimates that ground vibrations by heavy vehicles are responsible for half of urban building structural damage costs, equal to $.06 per mile.[17]

- Peter Miller and John Moffet estimate noise costs at $0.0014 to 0.0023 per automobile mile and three times higher for buses.[18]

- James MacKenzie et al. used estimates developed by Hokanson for the U.S. DOT to calculate total U.S. noise costs to be $9 billion annually, about $0.004 per VMT.[19]

- Transport 2021 estimates noise costs in the Greater Vancouver area equals $0.005 Canadian per km, or about $0.006 U.S. per mile.[20]

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[14] Apogee Research, *The Costs of Transportation*, Conservation Law Foundation (Boston), 1994, p. 161.
[15] Per Kågeson, *Getting the Prices Right*, European Fed. for Transport & Env. (Bruxelles), 1993, p 102.
[16] *The Full Cost of Urban Transportation,* Institute of Urban and Regional Development (Berkeley), Monograph #21 1975, p. 52.
[17] *Making Transportation Choices Based on Real Costs*, Konheim & Ketchem (NY), Oct. 1991
[18] *The Price of Mobility*, National Resources Defense Council (Washington DC), Oct. 1993, p.35.
[19] James MacKenzie, Roger Dower and Donald Chen, *The Going Rate*, World Resources Institute (Washington DC), 1992, p. 21.
[20] *Cost of Transporting People in the British Columbia Lower Mainland*, GVRD (Vancouver), 1993.

- Saelensminde uses previous studies to estimate noise costs for Norway, resulting in a range from $88 to $541 per capita annually, or about $0.01 to $0.054 per VMT.[21]

- Nils Soguel describes a Swiss survey in which residents indicated a willingness to pay an average of 70 francs (about US$55) per month to reduce traffic noise by half.[22] Several statistical strategies were used to minimize survey bias.

- The STAMINA model calculates the relative noise costs of trucks and automobiles.[23] It indicates that one heavy truck produces the same amount of noise as 63 automobiles at 50 km/hr, but at 100 km/hr this decreases to 25 cars per truck noise equivalent. Medium size trucks produce noise equivalent to 2 to 16 cars, depending on speed.

- The Washington State Department of Transportation uses a formula for calculating maximum investments in noise reduction that yields values ranging from $5,500 to $20,000 per exposed household, depending on noise level reduction.[24]

- The U.S. FHWA estimates noise costs at $.002 per vehicle mile.[25]

- A U.K. study found a high level of complaint and concern over traffic vibration.[26] Along roads with 500 or more vehicles per hour during peak periods, over 50% of residents are bothered by traffic vibration. However, field studies involving induced vibration in typical residential structures, and case studies showed only minimal and superficial structural damage that is likely to be caused by motor vehicle vibration

Variability: Noise impacts vary by vehicle type, vehicle condition, where it is driven, and when it is driven. Automobiles are generally quieter than either buses or motorcycles. Electric vehicles produce moderate motor noise at low speeds, and the same level of wheel noises as a gasoline vehicle, which is the primary source of noise at higher speeds. Noise costs are higher in urban areas, where there are more human ears, but this difference is not as great a might be expected, since the impact of a single vehicle in rural areas has a

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[21] Kjartan Saelensminde, *Environmental Costs Caused by Road Traffic In Urban Areas - Results From Previous Studies*, Institute for Transport Economics (Oslo), 1992.
[22] *Measuring Benefits from Traffic Noise Reduction Using A Contingent Market*, Center for Social and Economic Research on the Global Environment (London), 1994
[23] L.R. Rilett, *Allocating Pollution Costs Using Noise Equivalency Factors*, Transportation Research Board 1995 Annual Meeting (Washington DC), Paper 950938.
[24] Directive 22-22 *Noise Evaluation Procedures for Existing State Highways*, WSDOT (Olympia), 1987. Described in March 10, 1994 correspondence from Timothy Coats, WSDOT Traffic Noise Engineer.
[25] Douglass Lee, *Efficient Highway User Charges - Federal Highway Cost Allocation Study, Appendix E*, FHWA (Washington DC), May 1982.
[26] G.R. Watts, *Traffic Induced Vibrations in Buildings*, TRRL Report #246, (Crowhorne), 1990.

greater cost than an additional vehicle added to urban traffic. Noise also impacts wildlife, which implies additional environmental costs in addition to impacts on humans.

Conclusions: Several studies place average automobile noise costs at $0.001 to $0.02 per VMT, with higher costs for larger vehicles. Most studies underestimate total costs by relying on hedonic price surveys without scaling for non-residential and residual impacts. In other words, if people are willing to pay to avoid the worst traffic noise in their homes, they should be willing to pay more to completely eliminate traffic noise in all situations. For this reason these cost estimates can be increased by 2 to 8 times. More research is needed to better determine true total noise costs.

Automobile and van pool noise costs are estimated here at $0.01 per mile on urban roads and rural $0.005 on rural roads, based on existing cost estimates increased to take into account non-residential and residual costs. Electric cars are estimated to produce 30% of the noise cost of an automobile under urban conditions, and 60% during higher speed rural driving. Diesel bus noise is estimated to be 5 times greater than an automobile. Electric bus and trolley noise are estimated to be 3 times greater than an automobile, and motorcycles are estimated to be 10 times greater than an automobile. Rideshare passengers, bicycling, walking and telecommuting incur no noise costs.

Best Guess **Noise Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.010	0.010	0.005	0.008
Fuel Efficient Car	0.010	0.010	0.005	0.008
Electric Car	0.003	0.003	0.003	0.003
Van	0.010	0.010	0.005	0.008
Rideshare Passenger	0.00	0.00	0.00	0.00
Diesel Bus	0.050	0.050	0.025	0.04
Electric Bus/Trolley	0.030	0.030	0.015	0.024
Motorcycle	0.100	0.100	0.050	0.08
Bicycle	0.00	0.00	0.00	0.00
Walk	0.00	0.00	0.00	0.00
Telecommute	0.00	0.00	0.00	0.00

Automobile Cost Range: These are based on estimates cited above.

Minimum	Maximum
$0.002	$0.06

3.12 External Resource Consumption Costs

Definition: External costs of resources consumed by vehicle production and use.

Description: Automobile construction and use consume approximately 14% of U.S. aluminum, 34% of iron, 11% of steel, 71% of lead, 67% of rubber production, and over 50% of petroleum, which represents more than 20% of all energy consumption.[1] Actual resource consumption is even higher than these figures indicate because the U.S. imports five vehicles for each one it exports,[2] so additional resources are consumed in other countries to produce our cars.

Resource consumption is not necessarily a problem, but the price consumers pay does not cover all costs, including environmental impacts and various industrial subsidies. Iron and steel production involve extensive land use impacts from mining of both ore and coal, and produce significant air pollution and solid waste. Aluminum production involves mining, and consumes large amounts of cheap energy. Lead mining and productions produce hazardous wastes. Petroleum extraction, transport, and processing impose environmental impacts, dependency on foreign markets resulting in trade imbalances, military costs to maintain market access, reduction of non-renewable resources available for future generations, and tax subsidies. The majority of automobile ferrous metals and some other materials are eventually recycled,[3] but reprocessing still involves substantial energy consumption and pollution, and has not eliminated the need for mining.

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[1] *Facts and Figures '93,* American Automobile Manufactures Association (Detroit), 1993, p. 49 and 84; Homburger, Kell and Perkins, *Fundamentals of Traffic Engineering, 13th Edition*, Institute of Transportation Studies, UBC (Berkeley), 1992, p. 32-1.

[2] *Facts and Figures '93*, American Automobile Manufacturers Association (Detroit), 1993, p. 48.

[3] *Facts and Figures '93*, American Automobile Manufacturers Association (Detroit), 1993, p. 50.

Although production, and therefore consumption of these and other resources impose social costs, the most studied, and probably the greatest overall, are the external costs associated with energy, especially petroleum use. Energy externalities are therefore the focus of this section, and are used as a reference for other external resource costs.

Discussion: Motor vehicles are a major consumer of energy. In addition to propulsion energy, the energy equivalent of 400 gallons of oil or 5,600 kwh in electricity is embodied in the production of a typical automobile, which represents more than 10% of its typical lifetime energy use.[4] Petroleum imposes various externalities.[5] Peter Miller states:

> *"money spent at the pump falls significantly short of the true cost of energy used by the automobile due to the many externalities associated with oil production and use. Health and environmental costs include the destruction of natural habitat; water pollution; air pollution; greenhouse gas emissions; and the clean-up and habitat-loss costs of oil spills that are not directly paid by oil companies. Domestic oil exploration and extraction are subsidized by means of tax credits and other government incentives. And imported oil comes at the expense of multi-billion dollar expenditures of the Naval and Rapid Deployment Forces to protect U.S. shipping and our oil interests."*[6]

The external costs of energy consumption are reflected in the variety of publicly supported efforts to increase national energy efficiency. According to researchers John DeCicco and Marc Ross energy consumption imposes broad costs to the national economy. They state, *"Money spent on oil imports is mostly lost to the U.S. economy, and gasoline purchases provide relatively few jobs per dollar spent."*[7] David Greene and K.G. Duleep estimate petroleum externalities in a benefit/cost analysis of improving U.S. automobile fleet fuel

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[4] Warner and Glenys, *Canadian Green Consumer Guide*, Pollution Probe Foundation (Toronto), 1991.
[5] Darwin Hall, "Preliminary Estimates of Cumulative Private and External Costs of Energy," *Contemporary Policy Issues*, Vol. VIII, July 1990, pp. 283-307.
[6] Peter Miller and John Moffet, *The Price of Mobility*, NRDC (Washington DC), Oct. 1993, p.19.
[7] John DeCicco & Marc Ross, "Improving Automotive Efficiency," *Scientific American*, Dec. 1994, p. 56.

economy.[8] Their study, and similar analyses by the California Energy Commission,[9] include these external costs of imported oil:

- *Oil price benefits:* Because North America consumes over 25% of total world oil production, its demand has a monopsonistic effect. High U.S. demand increases international oil prices (the elasticity of world oil price with respect to U.S. demand is estimated at 0.3 to 1.1), imposing a financial cost on all oil consumers.

- *Transfer of wealth via monopoly pricing:* U.S. demand for imported oil raises the economic rent paid for oil, transferring wealth to oil producers. This reduces demand for U.S. goods and services, and lower economic growth. The price of oil over its competitive market price (estimated at $16/BBL) is considered a cost in their analysis.

- *Energy Security:* Energy security includes two sets of costs: economic and national security effects. The economic costs are the effects of sudden oil price changes on economic growth, inflation, and employment. For example, oil price shocks in 1973 and 1979 are considered to have caused subsequent recessions and extraordinary inflation. This is the result of the relatively long time needed for the economy to make price, capital, and technological adjustments to price changes. Until all adjustments are completed, the economy is inefficient and GNP growth is reduced. The second sets of costs are associated with strategic costs, especially, military expenditures in the Persian Gulf region. Although estimates of this cost are controversial, they consider $10/BBL an appropriate value for analysis.

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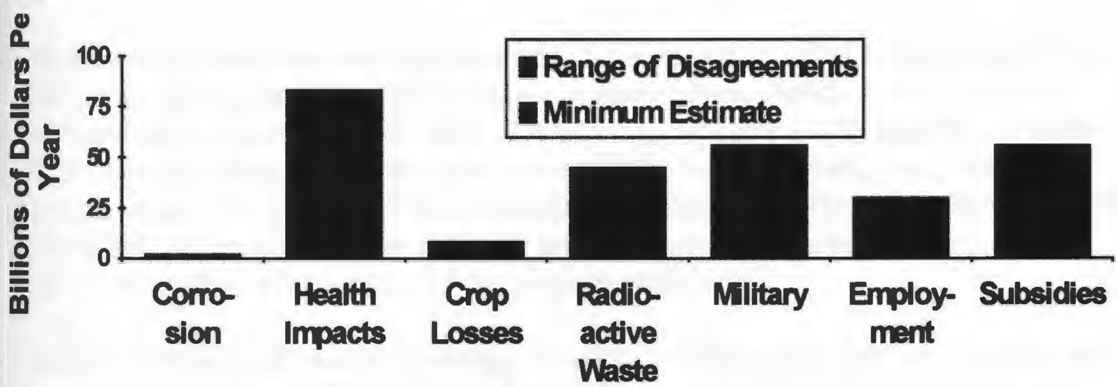
[8] David Greene and K.G. Duleep, "Costs and Benefits of Automotive Fuel Economy Improvement: A Partial Analysis," *Transportation Research A*, Vol. 27A, No. 3, pp. 217-235, 1993.
[9] *California Transportation Analysis Report; Technical Appendices* DRAFT, Feb. 1992.

Figure 3.12-1 shows external energy costs estimated by Harold Hubbard.[10] The first three cost categories: corrosion, health impacts, and crop losses are air pollution impacts considered in chapter 3.10. Radioactive waste disposal costs do not apply to petroleum use. The three remaining external motor vehicle energy costs include $12 to $55 billion in military expenditures to protect petroleum markets (this study was done before the war with Iraq and so this may be understated), $30 billion in reduced U.S. employment due to petroleum imports, and $43 to $56 billion in subsidies to the petroleum industry.

Figure 3.12-1 **Hubbard's Estimate of Energy Externalities**



This graph summarizes external costs of energy consumption, as estimated by Hubbard. Some of these costs apply to petroleum consumption.

Undertaxing of fuel is another external energy cost. In a study comparing actual taxes on energy with other classes of consumer products, Joe Loper concludes that fuel taxes (excluding user fees) are 30% lower than the average state and local taxes on general commodities, effectively providing a tax exemption to driving.[11] Although economists often treat taxes as transfer payments rather than costs, Douglass Lee points out that selected exemptions to broad-based taxes function the same as if all taxpayers paid the tax

[10] "The Real Cost Of Energy," Harold M. Hubbard, *Scientific American*, 264/4, April 1991, p. 36.
[11] Joe Loper, *State and Local Taxation: Energy Policy by Accident*, The Alliance to Save Energy (Washington DC), 1994.

and revenues were then returned as a subsidy payment.[12] This approach also recognizes that exemptions cause other taxes to increase to meet revenue demands.

Estimates:
(Note, although some estimates below are measured in VMT, this cost is actually based on fuel consumption rates, not vehicle mileage.)

- Apogee Research estimates external energy costs including government subsidies, tax breaks, maintenance of the Strategic Petroleum Reserve, and trade effects to total approximately $0.51 per gallon of gasoline, or about 2.5¢ per vehicle mile.[13]

- The California Energy Commission estimates energy security costs at $0.31/gallon of gasoline, or about $0.015 per automobile mile.[14]

- Greene and Duleep estimate the value of U.S. motor vehicle fleet energy conservation, including average savings of $13.8 billion in energy price reduction, $5.7 billion in reduced energy security costs, and $32.4 billion in reduced wealth transfer out of the U.S. (based on their "moderate" parameter values, averaging "high" and "low" oil prices, using 1993 dollars).[15] These benefits total about $50 billion for a fuel saving of about 150 billion gallons over a 30 year period, implying a marginal cost of about $0.33 per gallon, or about $0.017 per average vehicle mile.

- Harold Hubbard's estimates for energy security, unemployment, and tax subsidies for petroleum range from $85 to $141 billion.[16] Based on 52% consumed by motor vehicles and 2,300 billion annual miles, this equals $0.02 to $0.03 per vehicle mile.

- Douglass Lee estimates that motor vehicle's share of oil producer tax subsidies is $9 billion a year, Strategic Petroleum Reserve maintenance is $4.4 billion per year, and local, state and federal sales tax exemptions for fuel total $18.7 billion. This totals $32.1 billion annually or about $0.013 per vehicle mile.[17]

- Milton Copulos estimates petroleum import subsidies at $45 billion annually in 1989. He cites military costs, lost wages, and lost royalties.[18]

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[12] *Full Cost Pricing of Highways*, National Transportation Systems Center (Cambridge), p. 31.
[13] Apogee Research, *The Costs of Transportation: Final Report*, Conservation Law Foundation (Boston), 1994, p. 145-147, 158-159.
[14] *1993-1994 California Transportation Energy Analysis Report*, CEC (Sacramento), Feb. 1994, p. 29.
[15] David Greene and K.G. Duleep, "Costs and Benefits of Automotive Fuel Economy Improvement: A Partial Analysis," *Transportation Research A*, Vol. 27A, No. 3, pp. 217-235, 1993.
[16] "The Real Cost Of Energy," Harold M. Hubbard, *Scientific American*, Vol. 264 No. 4, April 1991.
[17] *Full Cost Pricing of Highways*, National Transportation Systems Center (Cambridge), 1995, p. 12.
[18] Milton Copulos, *Landmarc: National Magazine of Coal and Energy Issues*, J/F, 1989.

- Brian Ketcham and Charles Komanoff estimate energy subsidies for driving totals $33 billion a year, which equals about $0.015/mile.

- MacKenzie et al. argue that drivers should pay about half of micro-economic and security costs of importing petroleum, including maintenance costs for the Strategic Petroleum Reserve, totaling $25.3 billion dollars a year, about $0.012 per VMT.[19]

- Peter Miller and John Moffet's estimate of external costs of petroleum includes federal subsidies provided to the oil industry, micro-economic impacts, and military and other security costs. Their estimate ranges from $45 (assuming zero military and microeconomic costs) to $150 billion annually, or $0.015 to $0.05 per vehicle mile.[20]

- A study for the Western Regional Biomass Energy Program estimate the annual military costs of protecting U.S. access to Middle East petroleum supplies is $57 million per year, which averages $9.19 per barrel, or $0.22 per gallon.[21]

- The Office of Technology Assessment indicates average external fuel cost of $0.006 to $0.025 per vehicle mile based on these energy related cost estimates (billions):[22]

	Low Cost	High Cost
Monopsony cost of importing oil	$7.5	$21.6
Military costs related to oil use	5.0	20.0
Strategic Petroleum Reserve	0.2	0.2
Tax subsidies	0.0	3.0
Oil refineries environmental impacts	1.0	6.0
Gasoline distribution environmental impacts	0.0	5.0
Totals	$13.7	$55.8

- A Washington State Energy Office study found that telecommuting incurs a minor energy cost from increased residential energy use from heating, cooling and office equipment equal, plus some additional automobile trips.[23]

- Energy conservation investments by electrical utilities can be compared with motor vehicle fuel costs to determine whether petroleum conservation may be justified if energy policies were consistent across sectors. Utilities currently invest in energy conservation that is cheaper than a "hurdle rate," which ranges from about $0.03/kWh

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[19] James MacKenzie, Roger Dower and Donald Chen, *The Going Rate*, World Resources Institute (Washington DC), 1992, p. 17.
[20] *The Price of Mobility*, National Resources Defense Council (Washington DC), Oct. 1993, p.16.
[21] ENERGETICS & NEOS corporations, *The National Security Costs of Petroleum*, Western Regional Biomass Energy Program (Golden), June 1994.
[22] *Saving Energy in U.S. Transportation*, U.S. Office of Technology Assessment, 1994, p. 104-108. Also see pages 123-128 for discussion of energy security threat.
[23] Maureen Quaid and Brian Lagerberg, *Puget Sound Telecommuting Demonstration; Executive Summary*, Washington State Energy Office (Olympia), Nov. 1992.

to $0.13/kWh.[24] These rates are based on marginal costs of energy production, and often include adders for environmental impacts. Assuming an average energy conversion heat rate of 9,000 BTU/kWh, a gallon of gasoline equals 15 kWh. This implies that society should be willing to spend $0.45 to $1.95 per gallon of gasoline conserved, which would justify transportation energy conservation in many cases, since this often exceeds the $0.75 to $1.00 per gallon per-tax price of petroleum.

Since few of these estimates include environmental or non-use costs such as bequest or option values, they underestimate total costs. An indication that environmental and non-use costs of oil production and consumption may be substantial is the fact that the U.S. has prohibited or limited oil production in several areas where it is considered financially viable, including in Alaska's tundra, and off California's coast.

Variability: This cost depends on total energy use, including direct fuel consumption and indirect uses such as vehicle production energy.

Conclusions: Resource use, especially petroleum consumption, incurs external costs including environmental damage, tax subsidies, energy security, and national economic impacts. Estimates place these external costs between $25 to $150 billion per year for petroleum, which averages $0.005 to $0.03 per vehicle mile, based on roadway vehicles consuming half of total petroleum production.[25] Most lower estimates include only a few of the external costs identified. Although the exact value is difficult to determine, the middle to higher end of this range seems justified to include all external costs, including embodied energy and non-energy materials used in motor vehicle and road construction. Therefore, automobile resource consumption is estimated to impose external costs averaging $0.025 per mile.

This value is used for an average automobile under Urban Off-Peak conditions, with higher values for Urban Peak driving and lower values for Rural driving to reflect relative fuel efficiency and vehicle wear. The costs of other vehicles are estimated based on their

[24] Jim Lazar, Energy Economist, personal conversation, 2/23/94.

[25] *Facts and Figures '93*, American Automobile Manufactures Association (Detroit), p. 64.

relative fuel consumption. Electric car resource costs are estimated to be half that of an efficient automobile, to reflect the lower external costs of this energy source.[26] Rideshare passengers are estimated to add an incremental cost of 2% each, based on a 20% increase in fuel use for 10 passengers. Electric buses and trolleys are estimated to impose 50% the external environmental costs of diesel buses. Telecommuting energy costs are estimated at 10% of an average automobile for the increased energy consumption from residential heating and increased driving due to automobile availability.

Best Guess **External Resource Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.029	0.025	0.021	0.024
Fuel Efficient Car	0.014	0.013	0.011	0.012
Electric Car	0.007	0.006	0.006	0.006
Van	0.039	0.033	0.028	0.032
Rideshare Passenger	0.001	0.001	0.000	0.001
Diesel Bus	0.089	0.077	0.064	0.074
Electric Bus/Trolley	0.045	0.038	0.032	0.037
Motorcycle	0.012	0.010	0.009	0.010
Bicycle	0.000	0.000	0.000	0.000
Walk	0.000	0.000	0.000	0.000
Telecommute	0.003	0.003	0.002	0.003

Automobile Cost Range: The minimum is based on the estimate by Douglass Lee. The maximum estimate is based on a $150 billion total annual cost with an additional 10% for embodied energy and another 10% for non-energy resource costs.

Minimum	Maximum
$0.008	$0.078

[26] The main benefit of electric energy over petroleum is that it allows air pollution to occur outside of urban areas, which is incorporated in Chapter 3.10. At 0.5 kWh/mile, electric cars consume the same total energy as an 30 mpg car. While not all electric power uses imported petroleum products, it incurs other external costs, including SOx emissions, hydroelectric facility impacts, and nuclear waste production, depending on the marginal electrical power source.

3.13 Barrier Effects

Definition: Motor traffic impacts on the mobility, security, and satisfaction of pedestrians and cyclists, and its effects on their movement and activities.[1] Also called *severance.*[2]

Discussion: Roads are typically viewed as transportation links, but they are also barriers, especially to nonmotorized travel.[3] The barrier effect reduces walking and bicycling, and increased driving. It represents an increase in accident risk, and a degradation of the pedestrian and bicyclist environment. Barrier effect costs tend to be inequitable because they are imposed most on vulnerable and disadvantaged populations, including children, the elderly, and handicapped people. The UK *Environmental Assessment Manual* discusses this problem and provides instruction for measuring (but not monetizing) it.[4]

Robert Davis and Mayer Hillman argue that measured reductions in pedestrian and bicycle accidents may result from reduced travel by these modes rather than increased safety. Davis reports that the portion of British children walking on their own to school has decreased from 80% in 1971 to only 9% in 1990, due in part to motor vehicle accident risk.[5] A study of home-to-school transportation found similar patterns North America.[6] School principals cited "volume and speed of vehicular traffic" as the primary barrier to increased walking and bicycling by students. Hillman states,

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[1] Swedish National Road Administration

[2] Severance often emphasizes the impact of a new road on access within a community, while the barrier effect incorporates traffic impacts on all roads, old or new. J. Stanley and A. Rattray, "Social Severance" in *The Valuation of Social Cost*, Allen and Unwin (Editors), 1978; B.S. Hoyle and R.D. Knowles, *Modern Transport Geography*, Belhaven Press (London), 1992, p. 62.

[3] European Conference of Ministries of Transport, *Transport Policy and the Environment*, OECD (Paris), 1990, 134; Julian Hine and John Russel "Traffic Barriers and Pedestrian Crossing Behavior," *Journal of Transport Geography*, Vol.1 No. 4, 1993, pp. 230-239; J.M. Clark and B.J. Hutton, *The Appraisal of Community Severance*, U.K. DoT, TRRL (Crowthorne), Report #135, 1991.

[4] *Environmental Assessment Manual*, HMSO (London), 1993.

[5] Robert Davis, *Death in the Streets*, Leading Edge (North Yorkshire), 1992, p. 156.

[6] University of Florida, Dept. of Urban and Regional Planning, *Home-to-School Transportation Study*, Florida Department of Transportation (Tallahassee), 1990.

"Preferred patterns of behavior are altered and an increasing burden of responsibility is imposed on all road users, especially pedestrians, to reduce their exposure to risk. This is a social cost which has hardly been acknowledged and which certainly is not reflected in government transport or road safety policies."[7]

Susan Handy attributes reduced walking trips to a commercial district to the barrier effect created by a major arterial separating it from residential neighborhoods,[8] resulting in half the walking trip rate of an otherwise comparable community. A study by 1000 Friends of Oregon concludes that the portion of trips by walking, bicycling and transit in an area declines as its Pedestrian Environmental Factor (PEF) decreases.[9] Automobile oriented road designs (wide streets, cul de sacs, lack of sidewalk continuity) and high motor vehicle traffic speeds and volumes reduce the PEF. Traffic calming[10] and neotradtional planning[11] are based, in part, on the desire to improve neighborhood PEF.

Efforts to quantify this cost are currently limited to the Scandinavian literature. Both the Swedish[12] and the Danish[13] roadway investment evaluation models incorporate methods for quantifying barrier effects on specific lengths of roadway. Both methods involve two steps. First, a barrier factor is calculated based on traffic volumes, average speed, share of trucks, number of pedestrian crossings, and length of road way under study. Second, the demand for crossing is calculated (assuming no barrier existed) based on residential, commercial, recreation, and municipal destinations within walking and bicycling distance of the road. The Swedish model also adjusts the number of anticipated trips based on whether the road is in a city, suburb, or rural area, and the ages of local residents.

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[7] Mayer Hillman, "Foul Play for Children: A Price of Mobility," *Town and Country Planning*, Oct. 1988, pp. 331-332.
[8] Susan Handy, *Understanding the Link Between Urban Form and Travel Behavior*, TRB Annual Meeting (Washington DC), Paper #950691, January 1995.
[9] *The Pedestrian Environment*, 1000 Friends of Oregon (Portland), Dec. 1993.
[10] Peter Newman, Jeff Kenworthy, *Towards a More Sustainable Canberra*, Murdoch University, 1991
[11] Andres Duany, Anton Nelessen, Chris Duerksen and Walter Kulash, *Neotraditonal Town Planning*, Conference Proceedings, American Institute of Certified Planners
[12] Swedish National Road Administration, *Investment in Roads and Streets*, publication 1986:15E.
[13] Danish Road Directorate, *Evaluation of Highway Investment Projects* (undersogelse af storre hovedlandeveejsarbejder. Metode for effektberegninger og okonomisk vurdering), 1992.

Estimates:

- Kjartan Saelensminde estimates that the total cost of the barrier effect in Norway equals $112 per capita annually (averaging about $0.01 per vehicle mile), which is greater than the estimated cost of noise, and almost equal to the cost of air pollution.[14]

- A recent Dutch publication estimates that the barrier effect represents 15% of roadway costs to be considered in benefit/cost analysis (total costs are 50% economic [travel time, accident reduction, VOC], 30% noise, 15% barrier effect, 5% air pollution).[15]

Variability: As described in the Scandinavian literature, this impact depends on traffic speeds and volumes, and the demand for pedestrian and bicycle crossings.

Conclusions: The barrier effect is implied and described in much planning literature. In addition to direct costs to pedestrians, bicyclists and residents, it also imposes costs in terms of increased automobile dependency and use, and increased chauffeuring.

One might argue that there is a symmetry between the impacts of motor vehicles on pedestrian and bicycle travel and the delays non-motorized modes cause motor vehicles, resulting in a balance of "costs." However, casual observation indicates that pedestrians and bicyclists are much more delayed by motor vehicle traffic than vice versa, and that pedestrians and bicyclists frequently modify or forego trips due to heavy traffic, while automobile drivers seldom change their trip plans or reduce total travel because of delay, discomfort and danger imposed by pedestrian or bicycle traffic. It seems safe to estimate that there is at least an order of magnitude difference in the costs imposed by motor vehicle traffic on non-motorized travel compared with reciprocal impacts.

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[14] Kjartan Saelensminde, *Environmental Costs Caused by Road Traffic in Urban Areas-Results from Previous Studies*, Institute for Transport Economics (Oslo), 1992.

[15] Klaus Gylvar and Leleur Steen, *Assessment of Environmental Impacts in the Danish State Highway Priority Model*, 1983

Scandinavian estimates indicate that the barrier effect is a significant cost. There is no reason to believe that this cost is substantially different in Scandinavian countries than in North America. The Norwegian estimate of $0.01 per vehicle mile places this cost comparable to automobile noise, which seems reasonable and is used here to estimate automobile and motorcycle barrier costs. Transit vehicles are charged $0.025, which represents an average of the barrier effect cost for trucks in Danish and Swedish models.

Bicycling is estimated to incur 5% of an average automobile's barrier cost. Rideshare passengers, walking, and telecommuting incur no barrier costs. Although larger urban traffic volumes are balanced to some degree by higher speeds on rural roads, greater populations cause this cost to be highest in urban areas, especially during peak periods when traffic volumes are highest and the greatest demand exists for pedestrian and bicycle travel. For these reasons, the basic cost is applied to Urban Off-Peak driving, which is increased 50% for Urban Peak travel and decreased 50% for Rural driving.

Best Guess **Barrier Effect (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.015	0.010	0.005	0.009
Fuel Efficient Car	0.015	0.010	0.005	0.009
Electric Car	0.015	0.010	0.005	0.009
Van	0.015	0.010	0.005	0.009
Rideshare Passenger	0.00	0.00	0.00	0.00
Diesel Bus	0.038	0.025	0.013	0.023
Electric Bus/Trolley	0.038	0.025	0.013	0.023
Motorcycle	0.015	0.010	0.005	0.009
Bicycle	0.001	0.00	0.00	0.00
Walk	0.00	0.00	0.00	0.00
Telecommute	0.00	0.00	0.00	0.00

Automobile Cost Range: Because of limited research of this cost in North America, the range is somewhat arbitrarily estimated at 50% and 200% of the estimate developed here.

Minimum	Maximum
$0.005	$0.02

3.14 Land Use Impacts

Definition: External costs of land use impacts caused by roads and automobile traffic.

Description: Roads and driving impact land use directly, and indirectly by encouraging low density urban expansion (sprawl). These impose a variety of external costs.

Discussion: Transport and land use patterns are highly interactive. In the short term, land use patterns affect travel demand.[1] In the longer term, land use is affected by transport.[2] Travel patterns affect land use, which affects the natural and built environments, which affects economic, community and individual well being. These links explain why transport decisions can impose external land use costs. Measuring these costs is difficult because of the indirect nature of the impacts and the unique character of every area of land. Although little research has attempted to monetize them, these costs appear to be substantial.

Transportation as a Cause of Sprawl

An important consideration in this discussion is the degree to which roads and automobile use contribute to land use changes such as sprawl. The proper conceptual measure of such impacts is the *with and without* test: the difference in development that would occur with and without a road project or a certain level of driving.[3] Automobile use encourages sprawl by degrading the urban environment, by demanding large amounts of urban land for roads[4] and parking,[5] and by accommodating urban fringe development. Low density land use, in turn, leads to increased automobile use by reducing the viability of walking,

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[1] *Trip Generation Manual*, Institute of Transportation Engineers.
[2] Susan Hanson, *The Geography of Urban Transportation*, Guilford Press (NY), 1986, p. 4.
[3] C. van Kooten, *Land Resource Economics and Sustainable Dev.*, UBC Press (Vancouver), 1993, p. 86.
[4] See Chapter 3.7 for comparisons of the road space requirements of different modes.
[5] As described in Chapter 3.4, residential parking requirements tend to significantly reduce the number of housing units per acre, both by using land and by reducing the profitability of small units.

bicycling, and transit service.[6] This self-reinforcing driving/sprawl cycle continues until other forces, such as travel time, vehicle costs, and congestion become limiting factors.

The *Transportation and Traffic Engineering Handbook* states, "*Although there are other factors that play a role* [in urban sprawl], *reliance on the automobile has been most significant in this trend.*[7] Another popular transport engineering text states:

> *"Automotive transportation allowed and encouraged radical changes in the form of cities and the use of land. Cheap land in the outer parts of cities and beyond became attractive to developers, much of it being converted from agricultural uses. Most of the new housing was in the form of single-family homes on generously sized lots...Automobiles were easily able to serve such residential areas, while walking became more difficult, given the longer distances involved, and mass transportation found decreasing numbers of possible patrons per mile of route."*[8]

After studying the relationship between transport and land use patterns, researchers Peter Newman and Jeff Kenworthy found strong negative relationships between private vehicle use and nearly all measures of urban density and provision of automobile facilities (parking and road space), although causation is not proven.[9] Mark Hanson states, "*A motorized means of personal travel is necessarily the dominant transportation technology for serving highly dispersed trip origins and destinations.*"[10]

Daniel Solomon argues that the shift from urban to suburban development resulted to a large degree from the U.S. Federal Housing Administration's Minimum Property Standards (MPS), established in 1938, which effectively targeted federal housing loans to automobile oriented suburban developments. He states that, *"The MPS was based on the*

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[6] Susan Handy *How Land Use Patterns Affect Travel Patterns*, CPL Bibliography #279, 1992; Eric D. Kelley, "The Transportation Land-Use Link," *Journal of Planning Literature*, 9/2, Nov. 1994, p. 128-145.
[7] John Edwards, *Transportation and Traffic Engineering Handbook*, Institute of Transportation Engineers/Prentice Hall (Englewood Cliffs), 1982, p. 401.
[8] Homberger, Kell and Perkings, *Fundamentals of Traffic Engineering, 13 Edition*, Institute of Transportation Studies, UCB (Berkeley), 1982 p. 2-8.
[9] Peter Newman and Jeff Kenworthy, *Cities and Automobile Dependency*, Gower, 1989.
[10] "Automobile Subsidies and Land Use," *American Planning Association Journal*, Winter 1992, p. 60.

belief that American gridiron towns could not accommodate the automobile. It imposed a pattern of enclaves rather than a continuous urban fabric; traffic was restricted to arterials, and houses stood on curving cul-de-sacs."[11]

This low density, automobile oriented land use pattern is still taught to transport planners and traffic engineers as the preferred and acceptable road system because it best accommodates motor vehicle travel.[12] Only in 1994 did the Institute of Transportation Engineers publish a preliminary report on the development of street design standards for transit and pedestrian oriented communities that provides an alternative road development model based on neo-traditional street patterns.[13]

Two arguments are used against treating increased urban sprawl as a cost of transport. One is that sprawl is a land use management issue not a transport issue. In practice this is inappropriate because current land use management techniques are not completely effective.[14] Few governments have the strength to develop and enforce effective land use controls if strong demand exists, for example, where undeveloped land is easily accessible to urban areas.[15] Even with the best land use management system in place, transportation improvements have residual impacts that should be considered transportation costs.

Another argument for excluding sprawl as a cost, is that low density development may offer benefits that offset costs. For example, low density land use allows individuals to buy more land at a given price, including increased private greenspace. However, since

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[11] Daniel Solomon, "Fixing Suburbia," in *Sustainable Communities; A New Design Synthesis for Cities*, Sim Van der Ryn and Peter Calthorpe, Sierra Club Books, 1986, p. 22.
[12] Homberger, Kell and Perkings, *Fundamentals of Traffic Engineering, 13 Edition*, Institute of Transportation Studies, UCB (Berkeley), 1982, chapter 13.
[13] "An Informational Report: Traffic Engineering for Neo-Traditional Neighborhoods," *ITE Journal*, March 1994, p. 46.
[14] Knaap and Nelson, *The Regulated Landscape*, Lincoln Institute (Washington DC), 1992, Chapter 5.
[15] Harry Dimitriou, *Urban Transport Planning*, Routledge (NY), 1992, pp. 78-81.

sprawled land use increases the per capita area covered by buildings and pavement, the total amount of greenspace is reduced.

The benefits of sprawl are almost entirely internalized, so the best test of the hypothesis that total benefits exceed total costs would be to charge users for all external costs and see how much they are willing to pay. There is no obvious reason for society to subsidize these benefits. One justification might be that urban sprawl provides *external* benefits, but none have been demonstrated. At one time researchers investigated the possibility that low density land use reduces social problems such as crime, poverty, depression, and interpersonal conflict, but most studies find no association between density and crime or other behavioral problems when income and social class are factored in.[16]

This cost varies considerably by mode. Table 3.7-1 shows land use requirements of various modes as summarized by Émile Quinet. However, this is only one portion of this cost, since motor vehicle modes also degrade the urban environment and accommodate low density urban expansion, both of which further encourage sprawl.

Defining Land Use Impact Costs

Automobile oriented land use and sprawl are increasingly recognized as imposing external costs. One recent study rates "Inefficient Settlement Patterns," "Inefficient Infrastructure," and "Loss of Habitat due to Development" as first, second and third ecological and human health problems.[17] This study used surveys of environmental experts and cited a variety of other studies supporting the conclusions that urban sprawl is the region's most significant environmental problem because of its direct and indirect impacts. The California Air Resource Board also concluded that sprawl imposes an air pollution cost, and therefore

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[16] Andrew Baum and Yakof Epstein, *Human Response to Crowding*, Hillsdale, 1978.; Newman and Kenworthy, *Cities and Automobile Dependency*, Gower, pp. 89-92.
[17] *Report on Environmental Problem Ranking Process*, Capital Regional District (Victoria), Oct. 1994.

recommends development of denser, less automobile oriented communities.[18]

Transportation land use externalities can be grouped into five categories:[19]

1. *Environmental Impacts*

Biologically active lands such as wetlands, forests, farms, rangelands, and parks (collectively called *greenspace*) provide a variety of environmental and social benefits, including wildlife habitat, air and water regeneration, biological diversity and social benefits of agricultural production. These external benefits exist in addition to benefits to the land owner, and are not reflected in the land's market value because they are enjoyed by society as a whole.[20] These benefits are reflected in many ways, for example by increased value to adjacent real estate, improved community water quality, recreation and tourism, and in existence, option, and bequest values.[21]

Roads degrade environmental amenities and agricultural production directly by paving and clearing land, indirectly by encouraging increased development, sprawl and other disturbances, and by introducing new species that compete with native plants and animals. Ecological damage from roads and traffic is well documented.[22] Impacts include the loss, isolation, and disturbance of wildlife habitat, increased paved surfaces, clearing for road buffers, damage to unique physical features, road kills, and injuries. W. Roley states:

> *"The net effect on wildlife of automobile-dependent urban sprawl is the fragmentation of habitat and the isolation of these fragments and their wildlife populations from one another. The gravest threat to the survival of wildlife in developed areas around the*

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[18] *The Land Use-Air Quality Linkage; How Land Use and Transportation Affect Air Quality*, CEPA, Air Resources Board (Sacramento), 1994.

[19] For additional discussion of these costs see Engin Isin and Ray Tomalty, *Resettling Cities: Canadian Residential Intensification Initiatives*, Canadian Mortgage and Housing Corporation (Ottawa), Sept. 1993.

[20] Knaap and Nelson, *The Regulated Landscape*, Lincoln Institute (Washington DC), 1992, p. 126.

[21] Kopp and Smith, *Valuing Natural Assets*, Resources for the Future (Washington DC), 1993, pp. 10-19; and van Kooten, *Land Resource Economics*, UBC Press (Vancouver), 1993, pp. 157-187.

[22] See for example, Works Consultancy, *Land Transportation Externalities*, Transit New Zealand (Wellington), 1993; *Environmental Externalities and Social Costs of Transportation Systems*, Federal Railroad Administration (Washington DC) Aug. 1993; H.D. van Bohemen, *Habitat Fragmentation and Roads*, TRB Annual Meeting, Paper 950694, January 1995.

world is the reduction of both habitat and mobility of wildlife. The automobile, in other words, has become the greatest predator of wildlife."[23]

Prime farm land is often located near growing urban areas, making it highly susceptible to sprawl. Urban development of farmland is considered semi-irreversible. The total long term loss of farm production by urban sprawl is often underestimated. Studies estimate that from 1 to 5 acres are removed from farming for each acre that is actually developed due to land speculation and other influences of the "urban shadow."[24]

2. *Aesthetic Degradation and Loss of Cultural Sites*

Roads and traffic can reduce natural environmental beauty, cause urban blight and destroy cultural sites.[25] The *Transportation and Traffic Engineering Handbook,*[26] the Transportation Association of Canada's Environmental Policy and Code of Ethics,[27] the USDOT's *Environmental Assessment Notebook,*[28] and a Transit New Zealand study of transport externalities[29] all cite visual aesthetic degradation as major negative impacts of roads. Roads and the development they encourage can degrade landscape beauty in many ways.[30] The value of attractive landscapes is indicated by their importance in attracting tourism and increasing adjacent property values. Aesthetic impacts on the landscape can be evaluated using public and professional surveys.[31] Such techniques have been used to evaluate the visual impact of roads and traffic.[32] Ratings consistently became less favorable as the size of the road construction increased.

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[23] W. Roley, "No Room To Road," *Earthword #4*, 1993, p. 35.
[24] Bruce Pond and Maurice Yeates, "Rural/Urban Land Conversion I: Estimating Direct and Indirect Impacts," *Urban Geography*, Vol 14, pp. 323-347.
[25] B.S. Hoyle and R.D. Knowles, *Modern Transport Geography*, Belhaven (London), 1992, p. 54-57.
[26] John Edwards, "Environmental Considerations," *Transportation and Traffic Engineering Handbook*, Second Edition, Institute of Transportation Engineers/Prentice-Hall (Englewood Cliffs), 1982, p. 396.
[27] *TAC Newsletter*, Sept. 15, 1992
[28] *Environmental Assessment Notebook Series*, USDOT, 1975. In Homburger, 1992, p.29-4.
[29] Works Consultancy, *Land Transport Externalities*, Transit New Zealand, 1993, p.92.
[30] *British Columbia Scenic Highways Program Study*, MoTH (Victoria), October 1994, Chapter 3.3.
[31] Dunne and Leopold, *Water in Environmental Planning*, Freeman & Co. (NY), 1978, pp. 778-795.
[32] L. Huddart, "Evaluation of the Visual Impacts of Rural Roads and Traffic," TRRL, Report #355, 1978.

3. *Social Impacts.*

Many critics charge that automobile dependent transportation and an overemphasis on motor vehicle traffic flow in roadway design has negative impacts on society.[33] They argue that automobile oriented land use tends to degrade the public realm and the quality of residential neighborhoods, disperse activities that support community cohesion (local schools, stores, and other services), and discourage pedestrian and bicycle travel, reducing neighborhood interaction. Donald Appleyard reported a negative correlation between traffic volumes and various measures of neighborly interactions and activities, including number of friends and acquaintances residents had on their street, and the area that they consider "home territory."[34] he comments:

> *"The activities in which people engage or desire to engage in may affect their vulnerability to traffic impact. So many of these activities have been suppressed that we sometimes forget they exist...Children wanting to play, and people talking, sitting, strolling, jogging, cycling, gardening, or working at home and on auto maintenance are all vulnerable to interruption* [by traffic]...*One of the most significant and discussed aspects of street life is the amount and quality of neighboring. Its interruption or 'severance' has been identified as one of the primary measures of transportation impact in Britain."*[35]

Richard Untermann and Anne Vernez Moudon perform a more recent study of traffic impacts on neighborhoods and state,

> *"A deeper issue than the functional problems caused by road widening and traffic buildup is the loss of sense of community in many districts. Sense of community traditionally evolves through easy foot access--people meet and talk on foot which helps them develop contacts, friendships, trust, and commitment to their community. When everyone is in cars there can be no social contact between neighbors, and social contact is essential to developing commitment to neighborhood."*[36]

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[33] As evidence that roads often sacrifice social goals for the sake of motor vehicle traffic flow, compare actual road designs with roads optimized for social interaction described in Crowherst Lennard and Lennard, *Livable Cities Observed*, Gondolier Press (Carmel), 1995, or Christopher Alexander, et al., *A Pattern Language*, Oxford Press, 1977. In most areas, traffic needs have won over other design goals.

[34] Donald Appleyard, *Livable Streets*, University of California Press, 1981.

[35] Donald Appleyard, p. 35.

[36] Richard Untermann and Anne Vernez Moudon, *Street Design: Reassessing the Safety, Sociability, and Economics of Streets*, University of Washington (Seattle), 1989, p.3.

James Kunstler points out that an automobile oriented land use pattern and road system degrades the public realm (public spaces where people naturally interact) and reduce community cohesiveness.[37] Peter Freund and George Martin criticize the "placelessness" resulting when urban space is modified for automobile use, and from increased mobility provided by automobiles.[38] The report *Resettling Cities* mentions the following possible social problems associated with low density, sprawled land use (this document includes arguments both supporting and opposing these concerns):[39]

- Reduced choice of housing types suitable for an increasingly diverse population.
- Higher housing costs.
- Increased social alienation.
- Reduced social interaction.
- Decline of central cities and the rise of social problems there.

Merle Mitchell indicates that non-drivers who live in outer suburbs and rural communities may be "locational disadvantaged" due to relatively poor access to community services.[40] David Engwicht describes how automobile traffic reduces neighborhood social interaction.[41] He cites the dispersion of common destinations outside walking and cycling range from residences, degradation of walk and cycle environment, decline of corner stores, loss of public spaces suitable for casual social exchange, and increased fear of crime on city streets that are devoid of pedestrian traffic.

Automobile travel, urban sprawl, and middle-class flight to socially isolated suburbs are cited as contributors to a reduced sense of community, increased social conflict and

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[37] James Kunstler, *The Geography of Nowhere*, Simon & Schuster, (NY), 1993, Chapter 7.
[38] Peter Freund and George Martin, *The Ecology of the Automobile*, Black Rose (NY), 1993, p. 104.
[39] Engin Isin and Ray Tomalty, *Resettling Cities: Canadian Residential Intensification Initiatives*, Canadian Mortgage and Housing Corporation (Ottawa), 1993.
[40] Merle Mitchell, "Links Between Transport Policy and Social Policy" in *Transport Policies for the New Millennium*, Ogden et al. editors, Monash University (Clayton), 1994.
[41] David Engwicht, *Reclaiming our Cities and Towns*, New Society Publishers (Philadelphia), 1993, p. 45.

degradation of cities.[42] Steven Cochrun cites increased automobile use as a significant contributor to community design and individual behavior changes that reduce the vigor of local community.[43] Sociologist David Popenoe identifies several negative consequences of urban sprawl, including segregation by race and social class, economic inequity, fragmentation of local government, and reduced access for non-drivers, especially children and non-driving adults.[44] A recent Lincoln Institute of Land Policy newsletter article describes the impacts of sprawl on the poor:

> *"Land use patterns that put a premium on mobility actually disadvantage some segments of the population. Furthermore, a major cause of this poverty, in the opinion of many scholars and policymakers, is the gap between where these poor people live in central cities and where job growth is taking place in the suburbs. This transportation gap can be all but unbridgeable for low-wage workers who do not own cars, especially when public transit, where it exists, usually focuses on downtown and is often useless for conveying people to widely dispersed, suburban employment sites."*[45]

Some critics question whether low density land use is really socially disadvantageous. Hugh Stretton argues that the higher ratio of recreation sites per capita in Sydney, Australia compared with Tokyo, Japan indicates that lower density cities provide more resident benefits, ignoring the fact that preserving openspace often requires *increased* densities.[46] He cites survey findings that suburban residents prefer their current housing over inner-city apartments, but does not consider alternative residential patterns that may satisfy residents at higher densities. Stretton also claims that infill development is more expensive than building on greenfield (undeveloped) exurban land, but only mentions a limited number of costs (primarily utility lines) and ignores non-market costs.

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[42] Douglas Kelbaugh, *Housing Affordability and Density*, Washington State Department of Community Development (Olympia), 1992, p. 20; Elmer Johnson, *Avoiding the Collision of Cities and Cars*, American Academy of Arts and Sciences (Chicago), 1993, p. 7.

[43] Steven Cochrun, "Understanding and Enhancing Neighborhood Sense of Community," *Journal of Planning Literature*, Vol. 9, No. 1, August 1994, p. 92-99.

[44] David Popenoe, "Urban Sprawl: Some Neglected Sociological Consideration," *Sociology and Social Research*, Vol. 63, 1979, p. 255-268.

[45] "Restructuring our Car-Crazy Society," *Land Lines* 6/2, Lincoln Institute, March 1994, p. 2.

[46] Hugh Stretton, "Transport and the Structure of Australian Cities" in *Transport Policies for the New Millennium*, Ogden et al. editors, Monash University (Clayton), 1994.

4. *Municipal Service Costs*

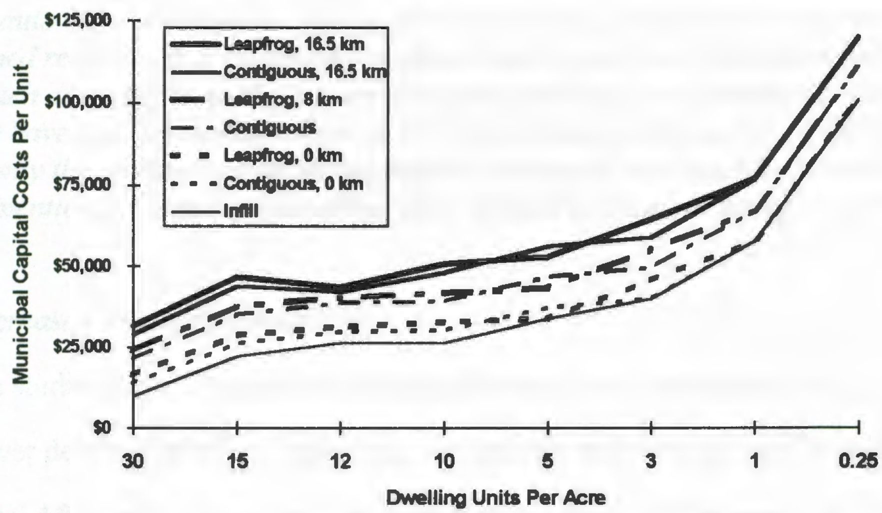
Several studies have found that low density land use requires significantly higher unit costs for most public services, such as utilities, roads, schools, and emergency services.[47] Results of two studies are shown in Table 3.14-2 and Figure 3.14-1.

Table 3.14-2 **Per Household Annual Municipal Costs for Different Residential Densities**[48]

Costs	Rural Sprawl	Rural Cluster	Medium Density	High Density
Units/Acre	1:5	1:1	2.67:1	4.5:1
Schools	$4,526	$4,478	$3,252	$3,204
Roads	$154	$77	$53	$36
Utilities	$992	$497	$364	$336
Totals	**$5,672**	**$5,052**	**$3,669**	**$3,576**

Per household service costs increase due to sprawl. These are mostly external costs.

Figure 3.14-1 **Residential Service Costs**[49]



This illustrates increased capital costs for lower density, non-contiguous development.

[47] James Frank, *The Costs of Alternative Development Patterns*, Urban Land Institute (Washington DC), 1989; *Impact Assessment of the New Jersey Interim State Development and Redevelopment Plan*, Office of State Planning, 1992; Eric D. Kelly, "The Transportation Land-Use Link," *Journal of Planning Literature*, Vol. 9, No. 2, pp. 128-145, Nov. 1994.

[48] Robert Smythe, *Density-Related Public Costs*, American Farmland Trust (Washington DC), 1986. Based on prototypical community of 1,000 units housing 3,260 people, 1,200 students.

[49] James Frank, *The Costs of Alternative Development Patterns*, Urban Land Institute, 1989, summarized from p. 40.

Since these studies focus on capital costs, the total incremental cost of sprawl is higher than indicated when operating costs are considered. Rural residents traditionally accepted lower levels of public services, including private water and sewer, and unpaved roads, but sprawl encourages new residents with higher expectations to move to exurban areas, so municipal governments face pressure to provide urban services to the urban fringe despite high unit costs.[50] Some communities use impact fees to internalize a portion of these costs, but in practice these seldom reflect full marginal costs.[51] Since these are fixed costs, they provide no incentive to use resources efficiently once development costs are paid.

These estimates are limited to residential development. The total costs of suburban sprawl are probably greater when commercial development costs are also included:

> *"Because the home and the workplace are entirely separated from each other, often by a long auto trip, suburban living has grown to mean a complete, well-serviced, self-contained residential or bedroom community and a complete, well-serviced place of work such as an office park. In a sense we are building two communities where we used to have one, known as a town or city. Two communities cost more than one; there is not only the duplication of infrastructure but also of services, institutions and retail, not to mention parking and garaging large numbers of cars in both places."*[52]

5. *Increased Transportation Costs*

Numerous studies show a negative correlation between land use density and automobile use.[53] Lower densities increase automobile dependency and mileage, resulting in higher travel costs. After reviewing current research on the relationship between land use and travel Duncan McLaren concludes, *"Empirical and modeled evidence supports the*

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[50] Judy Davis, Arthur C. Nelson, and Kenneth Dueker, "The New 'Burbs," *Journal of the American Planning Association*, Vo. 60, No. 1, Winter 1994.
[51] City of Lancaster (California), *Urban Structure Program*, 1994.
[52] Douglas Kelbaugh, *Housing Affordability and Density*, Washington Department of Community Development (Olympia), 1992, p. 17.
[53] John Holtzclaw, *Explaining Urban Density and Transit Impacts of Auto Use*, Sierra Club (San Francisco), 1994; Lawrence Frank, *Relationships Between Land Use and Travel Behavior in the Puget Sound Region*, WSDOT (Olympia), Report #WA-RD 351.1, 1994; Robert Dunphy and Kimberly Fisher, *Transportation, Congestion and Density: New Insights*, Urban Land Institute (Washington DC), 1993.

hypothesis that higher urban densities can reduce the need to travel."[54] A study of costs associated with different land use patterns in New Jersey concluded that a development plan which centralizes a greater portion of future growth would require 83% fewer new lane miles than continued sprawl that results in a greater amount of generated traffic.[55]

External Environmental and Social Benefits?

A 1978 report argues that highways provide external environmental and social benefits.[56] Few of these proposed but unsubstantiated benefits seem reasonable based on knowledge and sensibilities, and some seem outright silly. Here are typical quotations from the report:

Aesthetics: *"The freeway can provide open space, reduce or replace displeasing land uses, enhance visual quality through design standards and controls, reduce headlight glare, and reduce noise."* and *"Regarding the visual quality of the highway and highway structures, freeways may create a sculptural form of art in their own right. Some authors note that the undulating ribbons of pavement possessing both internal and external harmony are a basic tool of spatial expression."*

Wildlife: *"Freeway rights-of-way may be beneficial to wildlife in both rural and urban environments..."*

Wetlands: *"The intersection of an aquifer by a highway cut may interrupt the natural flow of groundwater and thus may draw down an aquifer, improving the characteristics of the land immediately adjacent to the highway."*

Native Vegetation: *"Roadside rights-of-way can be among the last places where native plants can grow."*

Neighborhood Benefits: *"Highways, if they are concentrated along the boundary of the neighborhood, can promote neighborhood stability."* and *"Old housing of low quality occupied by poor people often serves as a reason for the destruction of that housing for freeway rights of way."*

Social Benefits: *"Highways can increase the frequency of contact among individuals..."* and *"Good highways facilitate church attendance."*

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[54] Duncan McLaren, "Compact or Dispersed?" *Built Environment*, Vol. 18, No. 4, 1993, p. 268-284.

[55] Rutgers University Center for Urban Policy Research, *Impact Assessment of the New Jersey Interim State Development and Redevelopment Plan: Research Finding*, Office of State Planning, 1992, p.179.

[56] Hays Gamble and Thomas Davinroy, *Beneficial Effects Associated with Freeway Construction*, Transportation Research Board (Washington DC), Report 193, 1978

External Environmental and Social Benefits? - Continued

Recreation: "*Freeways cutting across, through, under, and around the cities afford an excellent opportunity for innovations in recreation planning and design.*"

Additional claimed benefits include improved air quality improvements, energy savings, and reduce traffic noise. Urban benefits include removal of blighted housing and slums, support of mass transit, reduced accidents, greater safety for pedestrians in general and school children in particular, improved community values, civic pride, increased social contacts between diverse social groups, increased upward social mobility, in-migration of better educated families, and increased housing opportunities for racial minorities. Land use benefits include suburban growth, decentralization, industrial parks, shopping malls, commercial development at freeway interchanges, and drive-in businesses.

Estimates:

1. *Environmental Impacts*

A Washington State Governor appointed advisory committee ranked land use impacts among the state's worst environmental threats, but below air and water pollution.[57] A recent study identified urban sprawl as the highest priority environmental problem in the Victoria (BC) area and cited numerous documents supporting this conclusion.[58] A survey of Vancouver area residents found 80% of respondents are concerned that not enough farmland and greenspace are being protected for future generations, and that 65% are willing to support higher density neighborhoods to protect greenspace.[59] These indicate that sprawl environmental costs are probably greater than zero and less than cost of air pollution. Using half of air pollution costs as a base, this averages $.025 per VMT.

2. *Aesthetic Degradation and Loss of Cultural Sites*

Little data is available on monetized roadway aesthetic costs. Segal estimates that a 3/4 mile stretch of Boston's Fitzgerald Expressway reduced downtown property values by as

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[57] *Environment 2010 Survey Results*, Washington Department of Ecology (Olympia), March 1990.
[58] *Environmental Problems Ranking*, CRD Roundtable on the Environment (Victoria), Oct. 1994.
[59] Viewpoints Research, *Public Attitudes Survey*, GVRD (Vancouver), April 18, 1994, p. 1.

much as $600 million in current dollars by blocking waterfront views.[60] Amortized, this cost averages $1.30 to $2.30 per vehicle trip over the Expressway. This is an extreme case, but indicates that aesthetic degradation from roads probably costs billions of dollars a year in reduced property values and non-market losses. Overall, aesthetic costs probably rank with other minor roadway environmental costs such as the barrier effect, water pollution and waste disposal, so a comparable estimate of $0.005 per average automobile mile seems appropriate, implying a national total annual cost of $11.5 billion.

3. *Social Costs.*

I have found no estimates of this group of costs. They are probably significant in total, and comparable to the environmental land use impact costs, so an estimate of $0.025 is used.

4. *Increased Municipal Costs*

Assuming that automobiles induce 50% of households to choose one step lower density in Table 3.14-1, half the average of the three incremental annual municipal cost increases ([($5,672-$5,052)+ ($5,052-$3,669)+($3,669-$3,576)] x 0.5 = $350), divided by 15,100 annual vehicle miles per household,[61] indicates this external cost averages $0.023 per mile.

5. *Increased Transportation Costs.*

Sprawled land use increases both users and external transport costs, but few studies attempt to quantify it. One approach is to use estimates of household vehicle ownership and mileage at different residential densities to calculate expected use travel costs per household. Applying an estimate developed by John Holtzclaw to the density values in Table 3.14-1, costs can be calculated using figures from Chapter 3.1. These estimates understate total sprawl costs because they use a constant transit accessibility index of 10, a factor that typically increases with density, and because the estimate of $0.10 per mile of

[60] Segal, *The Economic Benefits of Depressing an Urban Expressway*, 1981.
[61] *National Personal Transportation Survey: Summary of Travel Trends*, USDOT, 1992, p.18.

external costs is low, as will be discussed in Chapter 4. It also fails to incorporate user time and accident risk costs, which probably increase with sprawl.

Assuming that sprawl causes 50% of all households to choose a residence one step lower density in this table, the three incremental increases in household vehicle costs are averaged and divided by two. Divided by 15,100 average annual miles this cost averages $0.092 per mile, as shown in Table 4.14-2. If this is considered entirely a future cost then this value should be depreciated, but if it is considered a current cost (which seems appropriate where sprawl is both a current and future problem) no depreciation is needed.

Table 3.14-2 **Annual Household Auto Costs Under Four Densities**[62]

units/acre	1:5	1:1	2.67:1	4.5:1
Auto/Household	3.4	2.3	1.77	1.6
VMT/Household	28,822	18,603	15,100	13,233
Auto Ownership Costs ($2,600/year)	$8,840	$5,980	$4,602	$4,160
Auto Operating Costs ($0.134/mile)	$3,862	$2,493	$2,023	$1,773
External Costs ($0.10/mile)	$2,882	$1,860	$1,510	$1,323
Total Costs	$15,584	$10,333+	$8,135+	$7,256+
Incremental cost of reduced density	$5,251	$2,201	$879	n/a
Average of incremental costs	($5,251 + $2,201 + $879) ÷ 3 = $2,777			
Average incremental cost per household	$2,777 x 0.5 = $1,389			
Average cost per vehicle mile	$1,389 / 15,100 = 0.092			

This table shows estimate of increased automobile costs associated with lower density land use, with values modified to reflect national vehicle ownership and use.

A study comparing 1976 to 1990 Milwaukee area travel costs for 2,700 and 4,400 average people per square mile found that user transport costs increased 10% for the lower density option. These future costs should be depreciated, while including external costs would significantly increase the total. These factors are assumed to approximately cancel each other, giving an estimate of 10% of current user vehicle operating costs, or about $0.034 per mile. This represents the reimbursement that future residents would need for increased

[62] John Holtzclaw, *Using Residential Patterns and Transit to Decrease Auto Dependence and Costs*, National Resources Defense Council (San Francisco), June 1994. Vehicle ownership and annual mileage data from *National Personal Transportation Survey: Summary of Travel Trends*, USDOT, 1992, p. 12, 18.

travel costs resulting from current sprawled development. For a working estimate of sprawl's transportation costs, the estimates of $0.092 and $0.034 are averaged to $0.062.

Variability: These costs are associated with driving that contributes to the construction of roads, especially outside of urban areas, or that result in low density urban expansion. Ideally, this cost should be assessed specifically for each situation. Thus, sprawl costs would be higher in communities where sprawl impacts are greater, and for specific trips that accommodate and encourage urban expansion and low density development. Although most of this cost is assigned to automobile use, some transit services also contribute to sprawl, indicated by the portion of riders who access bus and trains by car.

Conclusions: Roads and driving cause land use impacts that impose environmental, aesthetic, social, municipal, and transport costs. If the amount of land devoted to roads and low density development was significantly reduced, society could be better off due to the preservation of greenspace, improved views, more interactive neighborhoods and communities, lower municipal costs, and reduced automobile dependency. This is not to say that these land use patterns offer no benefits, but most benefits are enjoyed by drivers and land owners, while costs are borne by society as a whole. Society must therefore be able to account for these external costs in order to avoid land use changes in which benefits do not offset total incremental costs.

There are few existing models or studies that measure the total of these costs. Individual estimates described above can be used to calculate a first-cut estimate of total sprawl costs, acknowledging that this is preliminary and more research is needed. The cost charged to drivers should take into account two additional factors. First, automobile use is not necessarily the only cause of sprawl, other influences such as mortgage and parking policies also encourage sprawl. Second, not all communities consider urban sprawl to be a problem. For these reasons, automobile use is only considered responsible for half of total sprawl costs, calculated below to be $0.07 per vehicle mile. This is charged to urban driving and telecommuting, because they encourage low density land use. Rural driving is charged at half this rate, on the assumption that it contributes less to sprawl. Ridesharing, public transit, bicycling, and walking decrease road building requirements and encourage higher densities, so incur no land use impact costs, although a sprawl cost should be assigned to commuter rail services that are primarily accessed by automobile.

Land Use Impact Cost Estimate (dollars per vehicle mile)

Environmental	$0.025
Aesthetic & Cultural	$0.005
Social	$0.025
Municipal	$0.023
Transport demand	$0.062
Total average sprawl cost	$0.140
50% reduction for other contributing factors	x 0.5
Sprawl cost charged to automobile use	**$0.07**

Best Guess **Land Use Impact Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.070	0.070	0.035	0.056
Fuel Efficient Car	0.070	0.070	0.035	0.056
Electric Car	0.070	0.070	0.035	0.056
Van	0.070	0.070	0.035	0.056
Rideshare Passenger	0.00	0.00	0.00	0.00
Diesel Bus	0.00	0.00	0.00	0.00
Electric Bus/Trolley	0.00	0.00	0.00	0.00
Motorcycle	0.070	0.070	0.035	0.056
Bicycle	0.00	0.00	0.00	0.00
Walk	0.00	0.00	0.00	0.00
Telecommute	0.070	0.070	0.035	0.056

Automobile Cost Range: This is currently a difficult cost to estimate due to limited research and data. The minimum estimate is based on just the increased municipal costs associated with sprawl. The maximum estimate reflects the higher range of each cost.

Minimum	Maximum
$0.02	$0.20

3.15 Water Pollution and Hydrologic Impacts

Definition: Water pollution and hydrologic impacts from vehicles, roads, and parking.

Description: Motor vehicles, roads and parking facilities are a major source of water pollution and hydrologic disruptions. These include:

Water Pollution
- Crankcase oil drips and disposal.
- Road de-icing (salt) damage.
- Roadside herbicides.
- Leaking underground storage tanks.
- Air pollution settlement.

Hydrologic Impacts
- Increased impervious surfaces.
- Concentrated runoff, increased flooding.
- Loss of wetlands.
- Shoreline modifications.
- Construction activities along shorelines.

These impacts impose a number of costs including polluted surface and ground water, contaminated drinking water, increased flooding and flood control costs, wildlife habitat damage, reduced fish stocks, loss of unique natural features, and aesthetic losses.

Discussion: Roads and motor vehicle use contribute significantly to water pollution and hydrologic problems. An estimated 46% of vehicles on U.S. roads leak hazardous fluids, including crankcase oil, transmission, hydraulic, and brake fluid, and antifreeze.[1] Between 460 and 600 million gallons of the 1.4 billion gallons of lubricating oils used in cars are either burned by the car's engine or lost in drips and leaks, and another 180 million gallons are disposed of improperly onto the ground or into sewers.[2] During use, crankcase oil picks up toxic chemicals and heavy metals. Millions of gallons of petroleum are released into water bodies from leaks and spills during extraction, processing, and distribution.[3] Leaking underground storage tanks, many used for motor vehicle fuel, cause additional

[1]Christopher Von Zwehl, Comments at New Jersey Senate Public Safety Committee public hearing on motor vehicle inspection legislation, Feb. 25, 1991, from *Facts and Figures 90*, AAMA.
[2] Helen Pressley, "Effects of Transportation on Stormwater Runoff and Receiving Water Quality," internal agency memo, Washington State Department of Ecology (Olympia), 1991.
[3] Peter Miller and John Moffet, *The Price of Mobility*, NRDC (Washington DC), Oct. 1993, p.50.

groundwater contamination. The oil spots on roads and parking lots, and rainbow sheens of oil in puddles and drainage ditches are a sign of this problem.

Studies show that runoff from roads and parking lots have high concentrations of toxic metals, suspended solids, and hydrocarbons,[4] and that automobiles are the primary source of toxic metals and organics.[5] Bioassay tests show mild to acute toxicity of highway runoff to various aquatic species.[6] Decreases in abundance and diversity of benthic organisms, and accelerated eutrophication of lakes has been attributed to urban runoff. Road de-icing salts incur significant environmental and material damage in many areas,[7] and roadside vegetation control is a major source of herbicide dispersal. An FHWA study indicates that water pollution is affected by road design, traffic volumes, climate and adjacent land uses (Table 3.15-1), and provides a model for predicting pollution from a particular roadway.[8]

***Table 3.15-1* Pollution Levels in Road Runoff Waters (micrograms per litre)**

Pollutant	Urban	Rural	Pollutant	Urban	Rural
Total suspended solids	142.0	41.0	Nitrate + Nitrite	0.76	0.46
Volatile suspended solids	39.0	12.0	Total copper	0.054	0.022
Total organic carbon	25.0	8.0	Total lead	0.400	0.080
Chemical oxygen demand	114.0	49.0	Total zinc	0.329	0.080

Roads and parking lots also have major hydrologic impacts. These include concentration of stormwater that causes increased flooding, scouring and siltation, increased flood control costs, reduced surface and groundwater recharge which lowers dry season flows,

[4] R.T. Bannerman, D.W. Owens, R.B. Dodds,and N.J. Hornewer, "Sources of Pollutants in Wisconsin Stormwater," *Water Science Tech.* Vol. 28; No 3-5; pp. 247-259, 1993; Works Consultancy, *Land Transport Externalities*, Transit New Zealand (Wellington), 1993, p. 33.
[5] Kevin Weiss, "Water Quality Impacts of Commuting," USEPA Office of Water Quality, 1993.
[6] Bioassay is a technique for testing the toxicity of substances by introducing them into the tanks of fish or other animals in laboratory conditions. Ivan Lorant, *Highway Runoff Water Quality, Literature Review*, Ontario Ministry of Transportation, Research and Development Branch, MAT-92-13, 1992.
[7] Field, R. and M. O'Shea, Environmental Impacts of Highway Deicing Salt Pollution., USEPA, Report No. EPA/600/A-92/092 Published in "Chemical Deicers and the Environment" (ed.) F. D'Itri.
[8] Eugene Driscoll, et al, *Pollution Loadings and Impacts from Highway Stormwater Runoff*, Publication Number FHWA-RD-88-007, FHWA (Washington DC), April 1990.

and constriction of streams into culverts that increase physical barriers to fish. A 1992 survey of 726 culverts in Washington State found that 36.4% interfere with fish passage at least sometimes, of which 17.4 were total blockages.[9] Reduced flows and plant canopy along roads can increase water temperatures. These impacts reduce wetlands and other wildlife habitat, degrade of surface water quality, and contaminate drinking water. In many cases the hydrologic impacts of road and urban runoff are more harmful to receiving waters than the effects of toxic pollutants.[10]

Quantifying these costs is challenging. First, it is difficult to determine exactly how much motor vehicles and roads contribute to water pollution problems since impacts are diffuse and cumulative. Although pollutants measured in roadway runoff are usually well below water quality standards, some build up in stream sediments where they can be toxic. Second, it is difficult to place a dollar value on water quality and flow. Even if we know the quantity of pollutants originating from roads and motor vehicle traffic and their general environmental impacts, we face the problem of monetizing costs such as loss of wildlife habitat, reduced wild fish reproduction, and contaminated groundwater.

New laws and policies designed to reduce pollution, prevent fuel tank leaks, and internalize cleanup expenses may reduce costs of some impacts, so it could be argued that current motor vehicle use imposes lower costs than has occurred in the past. However, growth in population density, total driving, and public concern about water quality will probably increase total costs, even if impacts per automobile mile decrease.

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[9] Tom Burns, Greg Johnson, Tanja Lehr, *Fish Passage Program; Progress Performance Report for the Biennium 1991-1993*, Washington Dept. of Fisheries, WSDOT (Olympia), Dec. 1992.
[10] Waste Management Group, *Urban Runoff Quality Control Guidelines for the Province of British Columbia*, BC Ministry of Environment, Environmental Protection Division (Victoria), June 1992.

Estimates:

- The California Energy Commission estimates major petroleum oil spill costs at $0.004 per gallon of gasoline, or about $0.0002 per mile, based on the calculated risk of a major oil spill such as the Exxon Valdez.[11]

- Paul Chernick and Emily Caverhill estimate average petroleum marine oil spill costs by multiplying the minimum Exxon Valdez cleanup cost estimate of $1.28 billion times 5 (because the cleanup only collected 20% of total oil released), for an estimated cost of $6.4 billion, or $582 per gallon spilled.[12] They consider this estimate conservative:

  "While Exxon has been criticized for doing too little, and spending too little, we are not aware of any criticism of Exxon spending too much. If cleaning up 20% of the spill was worth $1.28 billion, cleaning up all the oil must have been worth more than $6.4 billion. The first barrel in the environment probably has greater impact than the last 20% (After all, each animal can only be killed once. The practical difference between pristine water and slighly polluted water is almost certainly greater than the difference between very polluted water and slightly more polluted water), so the value of cleaning up all the oil would probably be much higher than $6.4 billion. The value of avoiding the spill in the first place must be greater than the value of cleaning it up, because returning the environment to its pre-spill pristine condition is desirable but impossible."

  This report cites estimates that oil tankers spill from %0.02 and %0.11 of their contents, for an estimated cost of $0.10 to $0.47 per gallon of imported crude oil, based on $582 per gallon. However, because of uncertainty concerning the application of Alaskan oil spills to other situations, the authors use a lower value of $0.026 per gallon to represent this cost in their own analysis of electrical generation impacts.

- In September 1994 an Alaska jury awarded $5 billion in damages to businesses and individuals harmed by the Valdez oil spill, which in addition to the $3 billion Exxon claims to have spent on cleanup implies a total cost greater than $8 billion, since the legal judgment does not compensate for all non-market damages. This estimate implies a cost greater than $728 per gallon of spilled oil.

- Douglass Lee estimates annual uncompensated oil spills average $2 billion, totaling about $0.001 per VMT.[13]

- Peter Miller and John Moffet cite leaking underground storage tanks, oil spill cleanup and road deicing costs, to estimate annual automobile water pollution costs at $3.8 billion, or $.0013 per VMT.[14]

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[11] *1993-1994 California Transportation Energy Analysis Report*, CEC, (Sacramento), Feb. 1994, p. 31.

[12] Paul Chernick and Emily Caverhill, *Valuation of Externalities from Energy Production, Delivery and Use*, Boston Gas Company (Boston), Dec. 1989, p. 85.

[13] *Full Cost Pricing of Highways*, USDOT, National Transportation Systems Center (Cambridge), p. 21.

[14] *The Price of Mobility*, National Resources Defense Council (Washington DC), Oct. 1993, p.50.

- Murray and Ernst estimate road salting costs at $4.7 billion (in 1993 dollars).[15]

- The Office of Technology Assessment study estimates that leaking fuel tanks and oil spills associated with motor vehicle use costs $1 to $3 billion per year in the U.S.[16]

- Transport 2021 estimates external water pollution costs from automobile use to be $0.002 Canadian per km, or $0.0025 U.S. per VMT, based on a review of studies.

- The Washington Department of Transportation (WSDOT) estimates that meeting its stormwater runoff water quality and flood control requirements will cost $75 to $220 million a year in increased capital and operating costs, or $0.002 to $0.005 per VMT.

Variability: Hydrologic impacts of stormwater depend on the amount of paved surface, so impacts are generally proportional to lane mileage. Water quality impacts are more closely related to vehicle mileage and maintenance.

Conclusion: Motor vehicles and roads impose a number of water quality and hydrologic costs, including roadway and parking lot stormwater runoff pollution, flooding and other hydrologic impacts, petroleum spills, road salting, and habitat loss (especially for fish and other aquatic animals). Available estimates of these costs range from $0.001-$0.005. However, no existing estimate incorporates all identified impacts, so they understate total costs. The WSDOT's cost estimate for meeting water quality standards for state highway runoff is notable because it alone exceeds most other estimates despite its limited scope, implying that water quality and hydrologic costs of roads and motor vehicle traffic are substantially higher than usually considered.

Here is an estimate of *total* water pollution costs from roads and motor vehicles:

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[15] Murray & Ernst, *Economic Assessment of the Environmental Impact of Highway Deicing*, EPA 1976.
[16] *Saving Energy in U.S. Transportation*, U.S. Office of Technology Assessment, 1994, p. 108.

1. State highways account for approximately 5% of U.S. road miles and 10% of lane miles, and carry about 50% of VMT.[17] An estimated 100 million commercial and 200 million residential parking spaces add approximately 30% to total road surface area, and more than 50% to urban road surface.[18] These figures indicate that total water pollution and hydrologic impacts are significantly greater than just state highway impacts. *State* highway runoff impacts are conservatively estimated here to represent one-third of *total* roadway runoff impacts, so the middle value of WSDOT's estimated cost of meeting its highway runoff mitigation requirements ($75 + $220 / 2 = $147.5) is tripled to include non-highway roads, parking spaces, and residual impacts ($147.5 x 3 = $442.5 million), and scaled to the entire U.S. road system ($442.5 x 50) for a total annual national runoff cost of $22.1 billion.

2. Add Douglass Lee's estimate of oil spills ($2 billion).

3. Add Murray and Ernst's estimate road salting costs ($4.7 billion)

This totals $28.8 billion per year, or about $0.013 per automobile mile. Note that this estimate does not include costs of residual runoff impacts, shoreline damage, leaking underground storage tanks, reduced groundwater recharge and increased flooding due to pavement, so it should be considered a conservative value. This cost is applied equally to all petroleum powered motor vehicles. Although it could be argued that larger vehicles require slightly more road surface and consume more petroleum products per mile, private vehicle owners are more likely to allow their vehicles to drip and to dispose of used fluids

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[17] FHWA Annual Statistics, 1992, assuming that interstates, freeways and principal arterials represent state facilities, and other roads are locally owned.

[18] Commercial parking estimate from Douglass Lee, *Full Cost Pricing of Highways*, National Transportation Systems Center (Cambridge), 1993, p.21. Residential parking spaces assume that there are slightly more parking spaces than registered automobiles. Parking lot area is calculated based on 250 parking spaces equal one lane mile.

incorrectly, so overall impacts are considered equal. Electric cars and trolleys are estimated to have water pollution cost half of an average automobile because they use few petroleum products, but still require roads and parking spaces. Bicycling, walking and telecommuting are not considered to impose any significant water pollution cost.

Best Guess **Water Pollution Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.013	0.013	0.013	0.013
Fuel Efficient Car	0.013	0.013	0.013	0.013
Electric Car	0.007	0.007	0.007	0.007
Van	0.013	0.013	0.013	0.013
Rideshare Passenger	0.00	0.00	0.00	0.00
Diesel Bus	0.013	0.013	0.013	0.013
Electric Bus/Trolley	0.007	0.007	0.007	0.007
Motorcycle	0.013	0.013	0.013	0.013
Bicycle	0.00	0.00	0.00	0.00
Walk	0.00	0.00	0.00	0.00
Telecommute	0.00	0.00	0.00	0.00

Automobile Cost Range: The Minimum is based on literature cited. The Maximum is the estimate developed above doubled to reflect costs not included in this estimate.

Minimum	Maximum
$0.001	$0.026

3.16 Waste Disposal

Definition: External costs of automobile waste disposal.

Description: Disposal of used tires, batteries, junked cars, oil and other semi-hazardous materials resulting from motor vehicle production and maintenance.

Discussion: Over 70% of Washington's moderate risk waste stream is from automobiles, and there is no reason to consider this atypical.[1]

Moderate Risk Waste	Percent
Used Oil (Primarily Automobile)	50%
Batteries (Primarily Automobile)	15%
Antifreeze (Primarily Automobile)	7%
Cleaners, Paints, Adhesives	21%
Pesticides, Other	7%

Used tires and junked cars also create significant disposal problems.[2] Tire piles create environmental and health hazards, especially when they catch fire. Although efforts are underway to find uses for waste tires, none have created enough demand to eliminate land fill disposal. Many junked cars sit for years before they are recycled. Some are simply abandoned and must be disposed of at public expense. Junked cars impose aesthetic impacts, and are sources of pollution from fluids, lead batteries, and metals.

These wastes impose a variety of environmental, human health, aesthetic, and financial costs, through improper disposal, residual impact even when proper disposal is observed, and because some disposal efforts are subsidized by general taxes. A number of recent laws and policies are intended to internalize these costs. Crankcase oil recycling networks

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[1] *Problem Waste Study (Moderate Waste)*, Washington Department of Ecology (Olympia), 1990, p. 12.
[2] *1992 Washington State Waste Characterization Study*, Washington Department of Ecology (Olympia) July 1993.

have been established, vendors are required to recycle used car batteries, and in some states a tire tax is dedicated to tire disposal. It is uncertain to what degree these policies will reduce external disposal costs.

There is the potential of overlap between water quality costs described in the previous chapter and waste costs described here, since both include waste crankcase oil. Water quality costs cover impacts of oil and other fluids that drip during vehicle use. Waste costs address impacts of oil and other fluids after their useful life, during disposal. A review of the previous chapter will show that there is no overlap in calculating these costs.

Estimates:

- Douglass Lee estimates the following external disposal costs:

Table 3.16-1 **Automobile External Waste Disposal Cost Estimate**[3]

Product	Annual Volume	Unit Costs	Total Annual Cost
Waste Oil	960 million quarts	$0.50	$0.5 billion
Scrapped cars	2.82 million	$25	$0.7 billion
Used tires	3 billion	$1	3.0 billion
Total			$4.2 billion, $0.002 per VMT

Variability: Impacts depend on vehicle design, construction and user waste management.

Conclusions: Waste disposal has been a significant problem of automobile production and use. Lee's estimate that U.S. external motor vehicle waste costs total $4.2 billion per year seems reasonable. Although it may overstate some waste costs if new management efforts are successful, it excludes other wastes altogether. This cost is applied equally to all motor vehicles. Although electric vehicles do not create waste oil, they do produce used

[3] *Full Cost Pricing of Highways*, National Transportation Systems Center (Cambridge), p. 31.

batteries, hulks and tires. As described in chapter 3.15 (Water Pollution), although buses and trams may produce more waste per vehicle, their waste tends to be managed better than those of private vehicles, so costs are considered equal.

Best Guess **Waste Disposal Costs (Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.002	0.002	0.002	0.002
Fuel Efficient Car	0.002	0.002	0.002	0.002
Electric Car	0.002	0.002	0.002	0.002
Van	0.002	0.002	0.002	0.002
Rideshare Passenger	0.00	0.00	0.00	0.00
Diesel Bus	0.002	0.002	0.002	0.002
Electric Bus/Trolley	0.002	0.002	0.002	0.002
Motorcycle	0.002	0.002	0.002	0.002
Bicycle	0.00	0.00	0.00	0.00
Walk	0.00	0.00	0.00	0.00
Telecommute	0.00	0.00	0.00	0.00

Automobile Cost Range: Due to the uncertainty of this cost and its relatively small magnitude, the minimum cost is zero. The maximum is 2.5 times the estimate used here.

Minimum	Maximum
$0.00	$0.005

4.0 Costs Totals

Chapters 3.1 through 3.16 provide Best Guesses of 20 costs for 11 modes under three travel conditions, totaling 660 individual estimates. These were put into a spreadsheet for calculating statistics. This chapter summarizes the results.

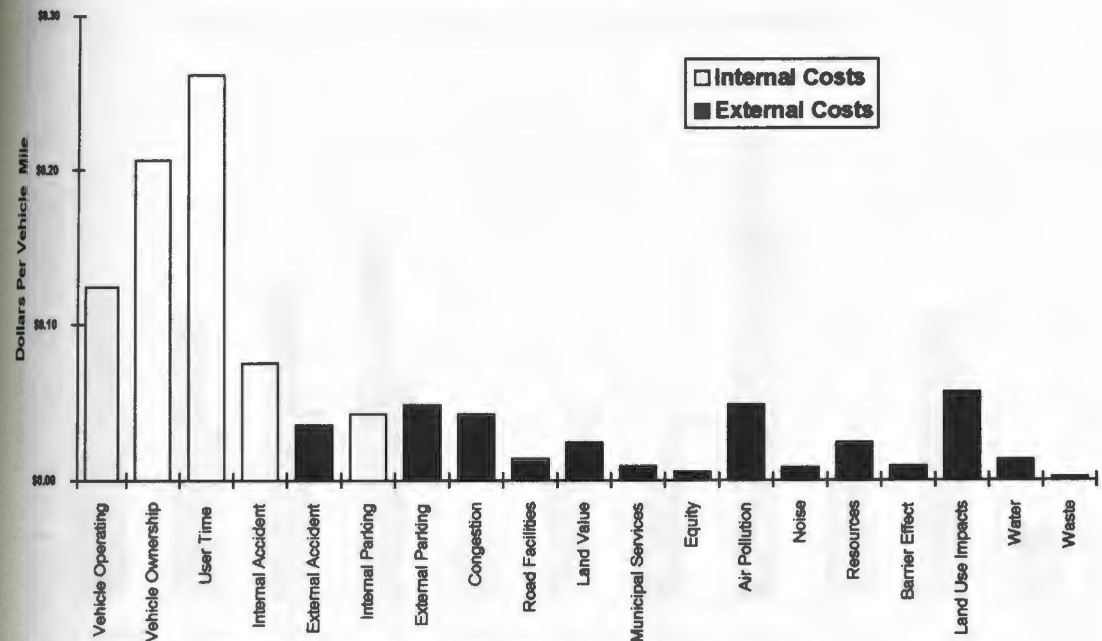
When reviewing these estimates it is important to remember:

- They include non-market costs such as users' travel time, accident risk, and environmental impacts, which is why they are higher than most travel cost estimates.
- Estimates are based on average vehicles and conditions. Costs may differ in specific situations.
- Some estimates describe costs *per passenger mile* not *per vehicle mile*, assuming average vehicle occupancy.

4.1 Summary Graphs

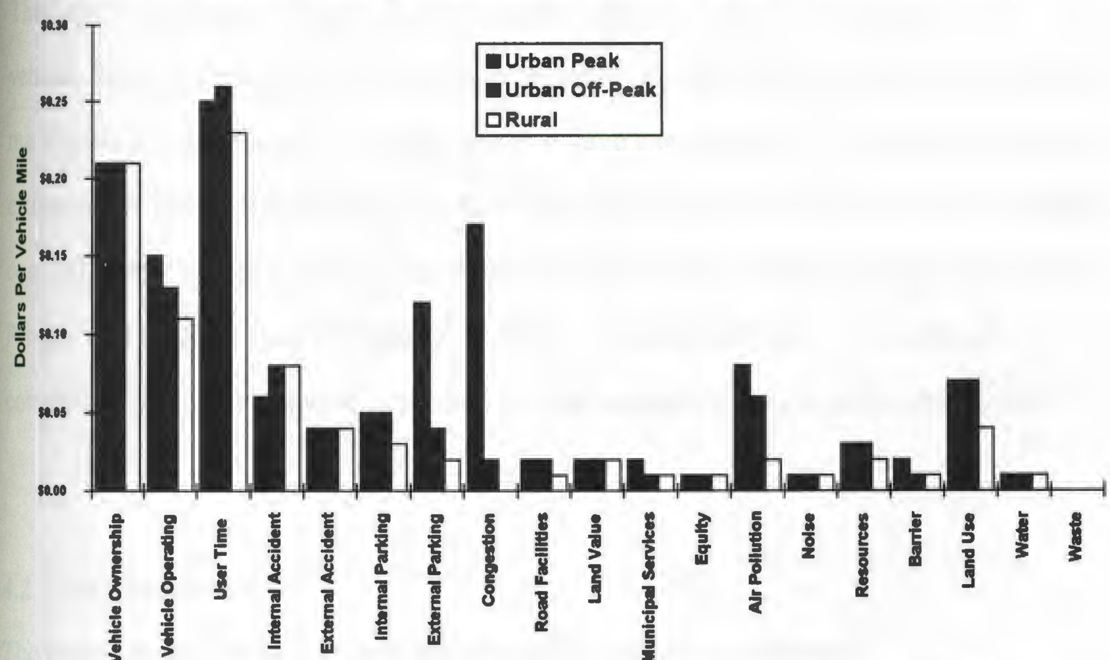
The following graphs summarize the results. Figure 4-1 shows average automobile costs per vehicle mile. Figure 4-2 shows costs for an Average Automobile traveling under Urban Peak, Urban Off-Peak, and Rural conditions. Figure 4-3 compares total average costs for each of the eleven modes.

Figure 4-1 **Costs Per Vehicle Mile for Average Automobile**



This graph shows average costs per vehicle mile.

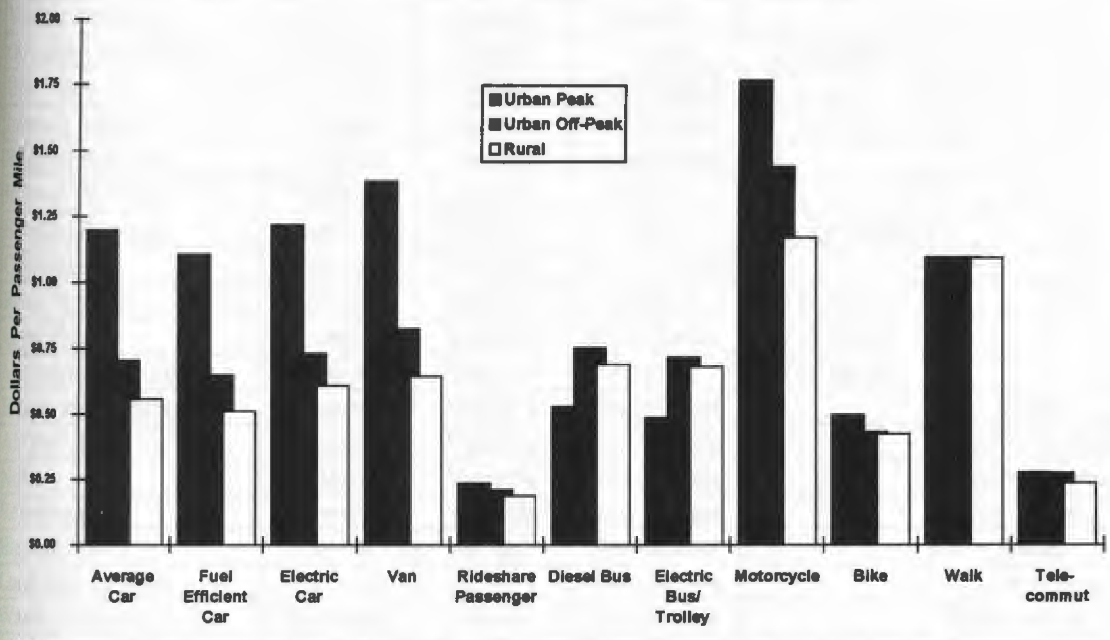
Figure 4-2 **Costs for Average Automobile Under Three Travel Conditions**



Some costs are significantly higher under urban and peak-period travel conditions.[1]

[1] Note that time and internal accident costs are higher per vehicle for off-peak than for peak travel. This is because urban peak driving tends to have lower vehicle occupancy than driving under other conditions.

Figure 4-3 **Total Costs Per Passenger Mile for Eleven Modes**



This graph compares total costs of each travel mode under the three travel conditions.

There is an important difference between public transit rider costs and typical private vehicle. Public transit ridership tends to experience increasing economies of scale, since many costs are fixed and most transit systems have excess capacity. Therefore, the cost estimates for Diesel Bus and Electric Bus/Trolley overstate marginal costs. The *marginal* cost of bus and trolley riders is best reflected in the Rideshare Passenger cost estimate.[2] Private vehicle costs tend to experience diseconomies of scale due to increasing congestion and other external costs, and so may understate long-run marginal costs.

4.2 Cost Distribution

The twenty costs can be grouped into categories defined in Table 4-1.

[2] Note that Rideshare cost estimates are based car pooling costs and do not include a user fare.

Table 4-1 **Transportation Cost Categories**[3]

Cost	Internal/ External	Fixed/ Variable	Market/ Non-market	Tax Based	Social/ Environmental
Vehicle Ownership	Internal	Fixed	Market		
Vehicle Operating	Internal	Variable	Market		
Operating Subsidies	External	Fixed	Market	Tax Based	
User Time	Internal	Variable	Non-Market		
Internal Accident	Internal	Variable	Non-Market		
External Accident	External	Variable	Non-Market		
Internal Parking	Internal	Fixed	Market		
External Parking	External	Fixed	Market	20% Tax Based	
Congestion	External	Variable	Non-Market		
Road Facilities	External	Variable	Market	Tax Based	
Land Value	External	Variable	Non-Market	Tax Based	
Municipal Services	External	Variable	Market	Tax Based	
Equity and Option	External	Variable	Non-Market		Social
Air Pollution	External	Variable	Non-Market		Environmental
Noise	External	Variable	Non-Market		Environmental
Resources	External	Variable	Non-Market		Env. & Soc.
Barrier Effect	External	Variable	Non-Market		Social
Land Use Impacts	External	Variable	Non-Market		Environmental
Water Pollution	External	Variable	Non-Market		Environmental
Waste	External	Variable	Non-Market		Environmental

This table indicates how costs are classified for analysis. Since internal variable costs, have the greatest effect on users' decisions, the distinction between internal and external, fixed and variable indicates the effect a cost is likely to have on travel demand.

Table 4-2 summarizes the cost distribution between five major cost categories for average automobile use. Figure 4-4 illustrates this same information in graph form.

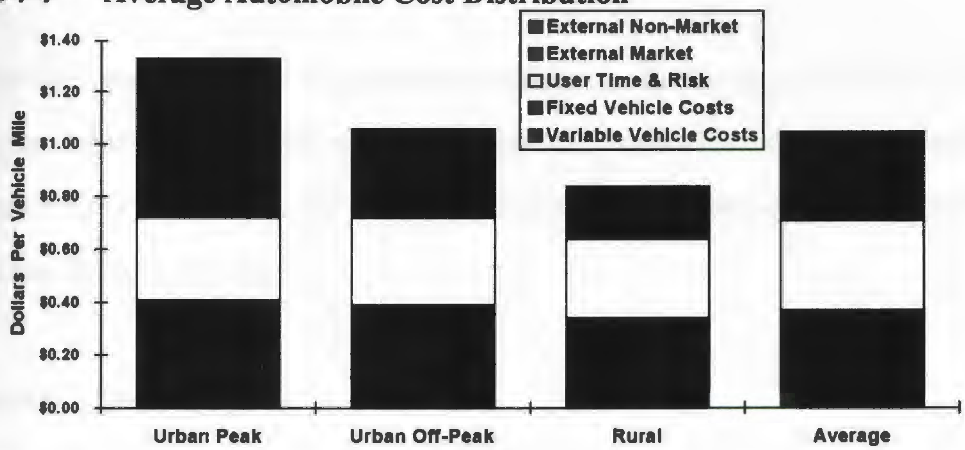
Table 4-2 **Cost Distribution per Vehicle Mile for Average Automobile**

	Urban Peak		Urban Off-Peak		Rural		Average	
	$/Mile	Percent	$/Mile	Percent	$/Mile	Percent	$/Mile	Percent
Variable Vehicle	$0.16	12%	$0.14	13%	$0.11	14%	$0.13	13%
Fixed Vehicle	$0.25	19%	$0.25	23%	$0.23	27%	$0.24	23%
User Time & Risk	$0.31	23%	$0.33	31%	$0.30	36%	$0.34	32%
External Market	$0.18	13%	$0.09	9%	$0.06	7%	$0.10	9%
External Non-Market	$0.43	33%	$0.25	24%	$0.14	16%	$0.24	23%
Total	$1.33	100%	$1.06	100%	$0.84	100%	$1.05	100%

Costs can be divided into five major categories. Variable Vehicle costs are one of the smallest categories, yet this is the cost category that most affects vehicle use. External costs are significant in each of the three driving conditions.

[3] These categories indicate general tendencies and are not absolute. There are exceptions, but they are considered minor.

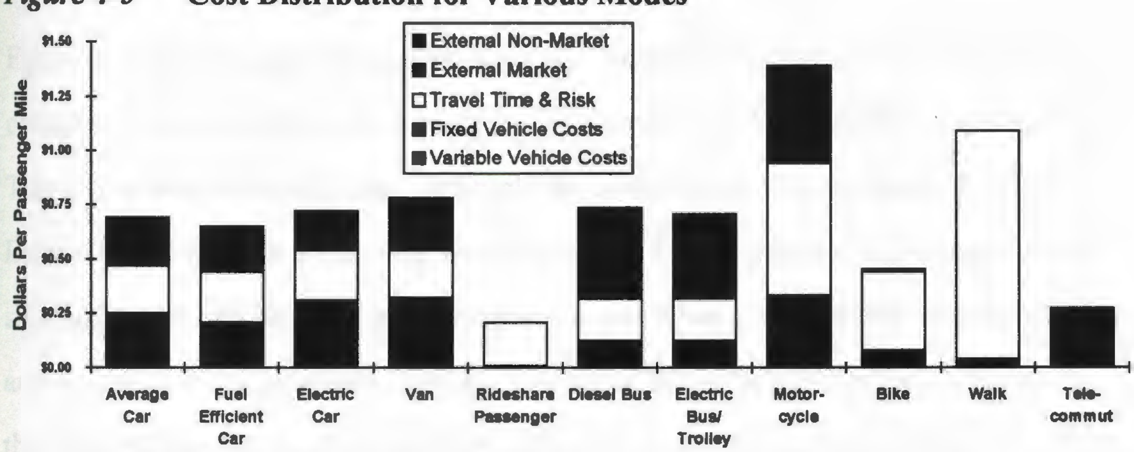
Figure 4-4 **Average Automobile Cost Distribution**



This graph illustrates the costs in Table 4-2.

Figure 4-5 shows costs for each mode divided into major categories. Travel time and accident risk is the largest cost category for most modes. Automobilefc operating costs alone are lower than those of transit riders, indicating that car owners usually find it cheaper to drive than to ride a bus. The ratio between internal and external costs varies significantly between vehicles. Non-market external costs as a percentage of total costs rank from motorcycles, vans, average automobiles, fuel efficient cars, electric cars, transit vehicles, telecommuting, bicycling, rideshare passengers, and walking. These differences in ratio between internal and external costs increase for Urban Peak travel.

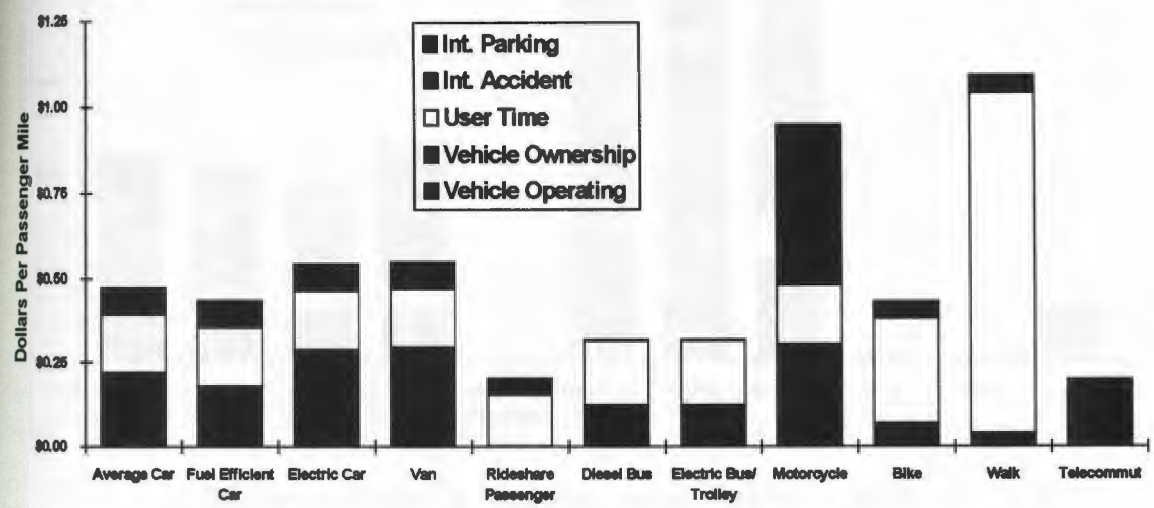
Figure 4-5 **Cost Distribution for Various Modes**



This graph shows the average values for five major cost categories.

Figure 4-6 shows the *internal costs* for each vehicle type further disaggregated. Travel time is the largest cost for most modes, and especially dominates bicycling and walking, so their total costs are extremely sensitive to the value used. Internal accident risk is the largest cost for motorcycling.

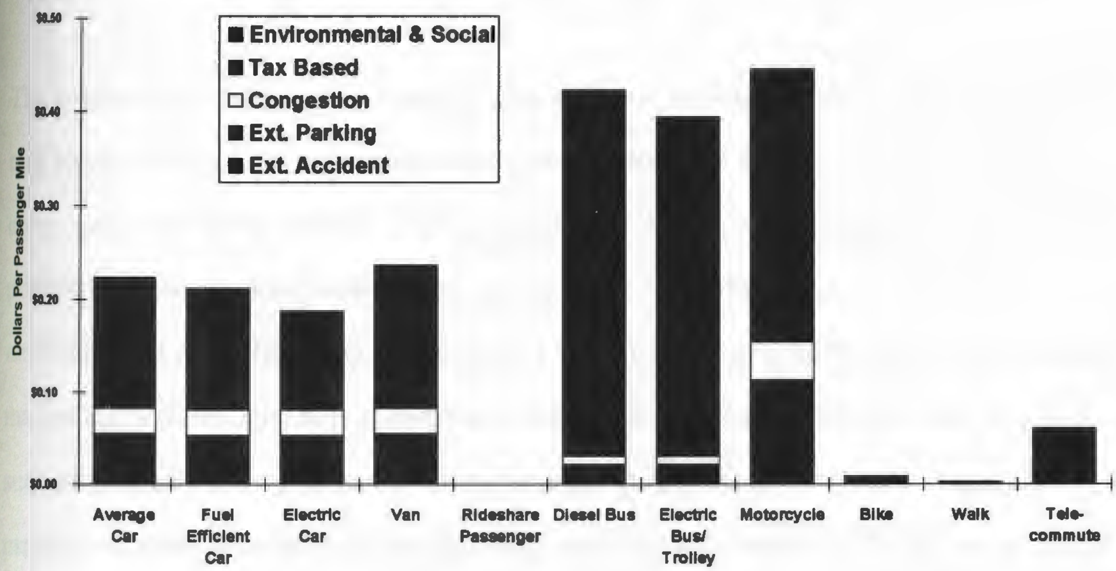
Figure 4-6 **Internal Costs**



This graph shows the internal costs of each travel mode.

Figure 4.7 shows external costs disaggregated. *Environmental and Social* is the largest category for automobiles and motorcycles, but is relatively low for other travel modes. This is true even of electric cars, although this cost is lower than for gasoline vehicles. External parking costs are another major category. During peak periods congestion is a significant cost, but becomes a relatively small cost when averaged over all mileage. Bus and trolley *average* passenger costs are dominated by tax based operating subsidies but the *marginal* cost of an additional rider, indicated by Rideshare Passenger, incurs virtually no external costs. Since transit passenger fares exceed marginal operating costs, the marginal cost to the system per additional rider is actually negative: the more paying passengers the bus system carries the lower the systems' average operating cost.

Figure 4-7 **Average External Costs**



This graph shows the external costs of each travel mode.

4.3 Total Transportation Costs

Table 4-3 shows estimated U.S. motor vehicle travel costs based on this analysis.

Table 4-3 **U.S. Motor Vehicle Costs, by Mile and Total**

	Mileage	Internal Costs		External Costs		Total Costs	
Units	billions	per mile	Total billions	per mile	Total billions	per mile	Total billions
Urban Peak	460	$0.71	$327	$0.61	$281	$1.32	$607
Urban Off-Peak	920	$0.71	$653	$0.34	$313	$1.05	$966
Rural	920	$0.64	$559	$0.20	$184	$0.84	$773
Total	*2,300*		*$1,539*		$778		$2346

This table summarizes total motor vehicle costs based on the estimates from this report.

That internal costs are the same for Urban Peak and Urban Off-Peak travel ($0.71 per mile) is unexpected, since the stop-and-go driving of peak period traffic increases travel time, stress and vehicle operating costs. However, this is offset by the lower automobile occupancy rates (approximately 1.2 average) compared with off-peak travel (greater than 1.5 average), resulting in comparable total travel time and higher accident risk costs.

This total of $2.3 trillion, which equals over 40% the U.S. Gross National Product (GNP), may seem unreasonably high, especially since this does not include other transportation costs such as air travel and rail. The explanation of this apparent anomaly is that a major portion of these costs are non-market, including personal time, accident risk, and environmental degradation. Only six of the twenty cost categories in this study are direct market costs (although these non-market costs impose significant indirect market costs such as medical care and disability costs from accidents and air pollution). Thus, the majority of these costs are not incorporated into GNP calculations. The market economy can be imagined as the tip of a pyramid that consists of the larger non-market human economy (unpaid travel time, housework, childcare, and volunteer activities that contribute to society), atop an even larger non-market natural economy that provides clean air, water, and beauty, in addition to marketed natural resources (Figure 4-8).

Figure 4-8 **Market, Human Non-Market, and Natural Non-Market Goods**

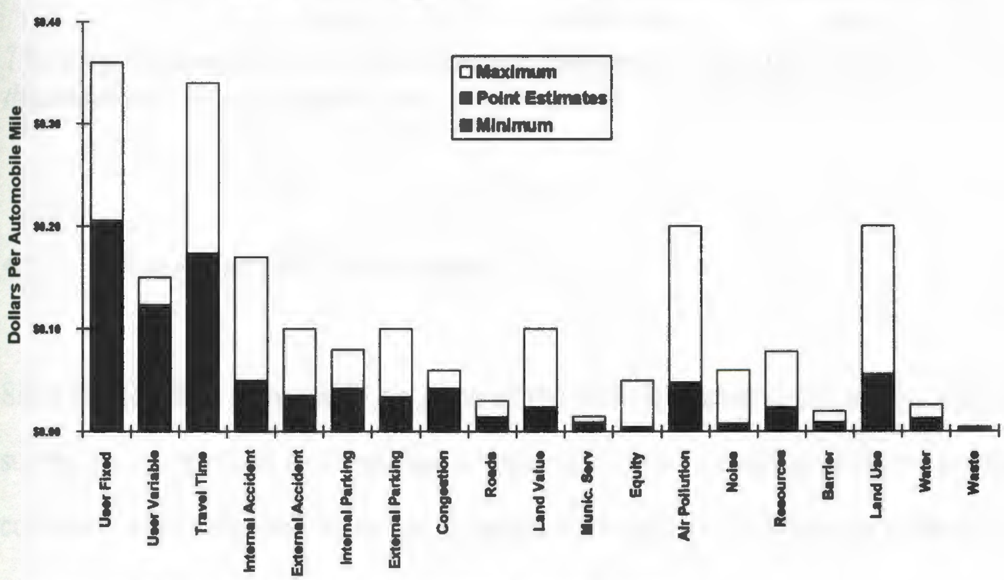
Markets represent only a small portion of all human benefits. A larger portion of benefits are provided by human non-market and natural non-market goods. Many of the costs of transportation represent losses of these goods.

Our total endowment of wealth, including non-market goods, is much larger than just market activities. We are richer than indicated by just our financial assets due to these non-market goods. Non-market costs, such as accident risk, lost time, and environmental degradation, represent the loss of non-market resources to ourselves, to other members of society, and to future generations. This estimate indicates what it would cost if we paid for the non-market goods consumed by transport.

4.4 Cost Ranges

As discussed in Chapter 1, section 1.10, the cost estimates developed in this report incorporate various degrees of uncertainty. Although point estimates are necessary for the analysis in this chapter, such estimates actually represent a range of possible costs that depend on particular circumstances and uncertain input data. The Minimum and Maximum estimates represent the widest reasonable range of average automobile costs. They can be used for sensitivity analysis. Figure 4-9 illustrates these ranges.

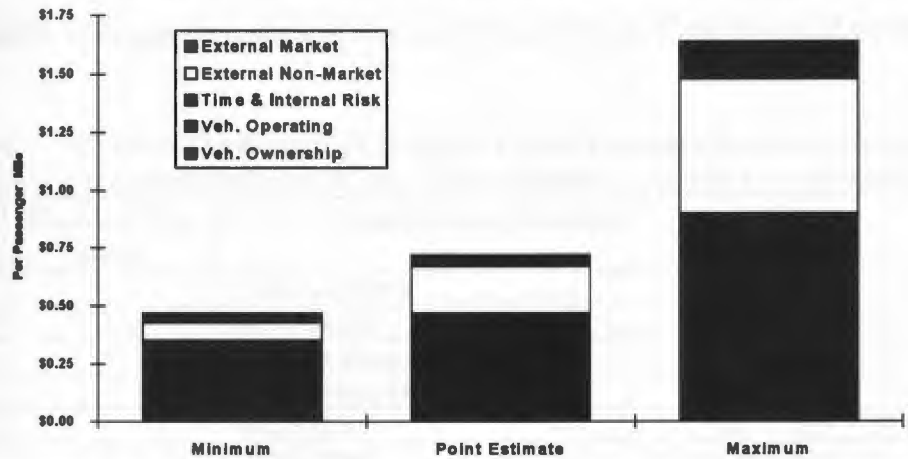
Figure 4-9 **Ranges of Average Automobile Costs**



This graph shows the most likely range for each cost.

Figure 4-10 shows Minimum, Point Estimate and Maximum costs by major category. The greatest variation occurs among travel time, internal accident risk, and external costs. Note that even the Minimum estimate shows external costs to be approximately equal to the Maximum estimate of variable vehicle costs (fuel, oil, tires, maintenance, and short term parking). Thus, even if the lowest reasonable values are used for each cost, externalities are still significant relative to the costs most often considered in private and public transportation decisions.

Figure 4-10 **Ranges of Average Automobile Costs by Major Category**



This graph compares cost range by major categories. Even the lowest estimate indicates that external costs are significant.

4.5 Survey Test of Cost Estimates

Since limited data is available on some of the costs included in this study, a preliminary survey was performed to determine whether the public's ranking of transportation costs is consistent with this study's results. One hundred eleven (111) surveys were distributed to households randomly selected across North America. Of those, 11 were returned as undeliverable.[4] Thirty-eight completed survey forms were received.

The survey asked respondents to identify how serious they consider various transportation problems. The responses were numbered from 1 (Very Serious) to 4 (Not At All Serious). Table 4-4 shows the survey results. These indicate that the public considers social and environmental transportation costs significant. Even the lowest ranking cost, *Ugliness of roads*, has a value indicating that respondents, on average, considers it between "Not Very Serious" and "Somewhat Serious." Costs ranked according to the survey show a strong correlation to the ranking of average automobile costs in this study, with the exception of urban sprawl. This may be explained by the technical nature of many sprawl costs.

Table 4-4 **Public Survey and This Study's Cost Estimate Ranking Compared**
"Below is a list of transportation problems. Please indicate how serious you consider each."

Survey Rank	Rank In This Study	Transportation Problems	Survey Average	Variance
1	1	Traffic accidents	1.53	0.72
2	3	Air Pollution	1.59	0.45
3	5	Excessive energy consumption.	1.74	0.37
4	4	Traffic congestion	1.89	0.84
5	7	Barrier Effect	2.19	0.50
6	8	Traffic Noise	2.20	0.87
7	9	Mobility problems for non-drivers	2.24	0.50
8	6	Harm to wildlife caused by roads and traffic.	2.27	0.64
9	2	Urban sprawl	2.37	0.86
10	10	Ugliness of roads	2.79	0.90

This table shows that survey respondents gave similar rankings to transportation problems as the cost estimates in this survey. Note that the lower the average value, the more serious respondents consider the problem.

A second question asked respondents to identify how important they consider various transportation goals (Table 4-5). "Very Important" counted as a 1, while "Not At All Important" counted as a 4. Although these questions are more difficult to compare

[4] Additional letters were probably undelivered but not returned across the international border

directly, the results are consistent with this study's cost estimates. The top ranking of *Develop a more diverse transportation system*, and *Provide better transport to poor, handicapped, and elderly*, support the concept of transportation equity and option value, and indicate that these costs are, if anything, underestimated in this study. Similarly, the high ranking of *Reduce environmental impacts* and *Reduce urban impacts* indicate that the public perceives environmental degradation and negative social impacts to be significant external costs of our current transport system.

Table 4-5 **Survey Ranking of Transportation Goals**
"Please indicate how important you consider the following transportation goals."

Rank	Question	Average	Variance
1	Develop more diverse transportation system.	1.26	0.20
2	Provide better transport to poor, handicapped, and elderly.	1.58	0.44
3	Reduce environmental impacts.	1.74	0.81
4	Reduce urban impacts.	1.77	0.39
5	Reduce/avoid urban sprawl	2.21	0.92
6	Accommodate increased driving	2.34	0.81

While its small size and methodological limitations prevent this survey from providing conclusive results, it supports this study's estimates of transportation costs and demonstrates that surveys can be useful for this research. Survey results indicate that the magnitudes of this study's cost estimates are appropriate, and that costs which have previously been ignored in transport planning, such as Equity, Option Value, the Barrier Effect, and Land Use Impacts, may be even greater than estimated here.

4.6 Summary

If you ask people what it costs to drive they typically mention vehicle operating expenses, which average approximately 12¢ per mile for a typical car. Some may also include a portion of vehicle ownership costs, which averages about 21¢ per mile. A few may also mention the value of travel time and accident risk. These however are only a portion of total costs. The full cost of driving includes all of these internal costs plus a significant number of external costs. Total costs actually range from about $0.84 per vehicle mile for rural driving to $1.33 for urban peak driving. Of course there is considerable variation in the cost of any specific trip, but these estimates, and variations for different travel modes and specific conditions, provide a reasonable basis for analyzing true transport costs.

Some specific cost estimates used here are of uncertain precision, but this does not change the analysis conclusions. The *existence* of each cost has been demonstrated, double counting is avoided, and the best available data are used. Even using the lowest reasonable cost estimates, total external costs are significant.

5.0 Travel Elasticities and Generated Traffic

Transportation improvements and cost reductions can encourage more and longer trips, changes in travel patterns, and land use changes which require special consideration when assessing benefits and costs. Current transportation planning often fails to do this, resulting in incorrect conclusions. This chapter describes how increased travel and related impacts should be assessed, and provides analysis tools for doing this.

5.1 Introduction

Transportation improvements that reduce user costs tend to increase travel and divert trips from other routes, times and modes. This is called *generated traffic*. Economic analysis requires that all incremental (net) benefits and costs be including in the evaluation of policies, programs and projects. Incremental costs and benefits to existing trips are relatively easy to determine, but special consideration is needed to determine net benefits and costs of generated traffic.

Generated traffic has three important implications on transportation decision making. First, as discussed in greater detail later in this chapter, generated travel tends to provide relatively little user benefit, since these are trips that users chose to forego when traffic conditions are suboptimal.

Second, it erodes a portion of the congestion reduction benefits that are often predicted for transportation improvements.[1] A recent report by the UK Standing Advisory Committee on Trunk Road Assessment concludes, *"These studies demonstrate convincingly that the economic value of a [road] scheme can be overestimated by the omission of even a small amount of induced traffic. We consider this matter of profound*

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[1] This is the same as the "take back" or "snap back" effect found by energy planners, in which consumers increase their energy use a result of conservation efforts that reduced their unit energy costs.

importance to the value-for-money assessment of the road programme."[2] A recent study found that the ranking of preferred projects changed significantly when generated traffic "feedback" is incorporated into conventional project assessment analysis.[3] Specifically, capacity expansion options were found to provide less congestion reduction benefit and negative air emission effects, while demand management and No Build options have more relative benefits.

The third implication is that generated travel increases total transport costs, including the external costs identified earlier in this report. While users' marginal benefits exceed their marginal costs of increased travel (if not, users would not take the additional trips), these benefits do not necessarily exceed *total* incremental costs. Generated traffic, therefore, may create more costs than benefits.

Traffic models used in some large urban areas incorporate generated traffic feedback, and U.S. Clean Air laws require increased use of such models. But models used in medium and small communities usually omit this step, and generated traffic costs are usually ignored in the economic analysis of specific projects.[4] Motor vehicle use is frequently assumed to grow at a constant rate, unaffected by road improvements. Ignoring the effects of generated traffic in economic analysis tends to overstate benefits and understate costs of roadway improvements, leading to non-optimal transport investments. A common excuse for this omission is that no tools exist to predict how much traffic will be generated or to determine resulting net costs. These excuses are no longer justified.

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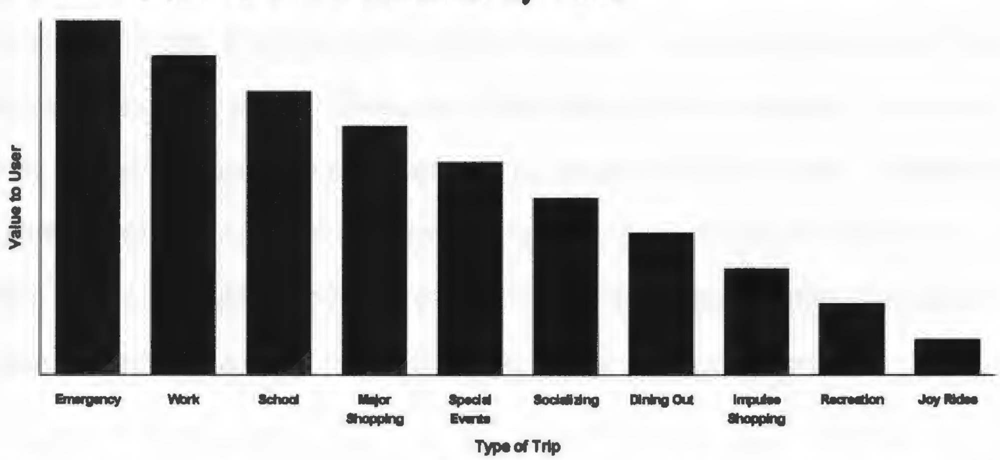
[2] SACTRA, *Trunk Roads and the Generation of Traffic*, UKDoT, HMSO (London), 1994.
[3] Pro. Robert Johnston and Raju Ceerla, *A Comparison of Modeling Travel Demand and Emissions With and Without Assigned Travel Times Fed Back to Trip Distribution*, Institute of Transportation Studies, University of California at Davis, 1994. Submitted to the *Journal of Transportation Engineering*.
[4] H.C.W.L. Williams and W.M. Lam, "Transport Policy Appraisal with Equilibrium Models I: Generated Traffic and Highway Investment Benefits," *Transportation Research B*, Vo. 25, No 5, pp. 253-279, 1991.

5.2 Transportation Elasticities

A basic rule of economics (and common sense) states that products which are cheaper or more convenient will be used more. This applies to transportation, not only for financial costs, but also for improvements in travel time, convenience and comfort. Economists measure the sensitivity of this effect using *elasticities*, which is defined as the percentage change in consumption caused by a percentage change in user costs.[5]

Let's consider how a reduction in price or an increase in travel speed increases driving. First, consider the elasticity of all travel. For example, rank all of the trips that you might consider making during a certain time period from highest to lowest value, as illustrated in Figure 5-1. There are typically some high value trips (such as urgent medical services, commuting, major shopping trips, special social and recreational events), some medium value trips (such as less important errands and less enjoyable social and recreation activities), and some low value trips (such as frivolous errands and the least enjoyable social and recreation activities). If travel costs increase you will forego the lower value trips, but take them if prices decline.

Figure 5-1 **Individual's Travel Ranked by Value**

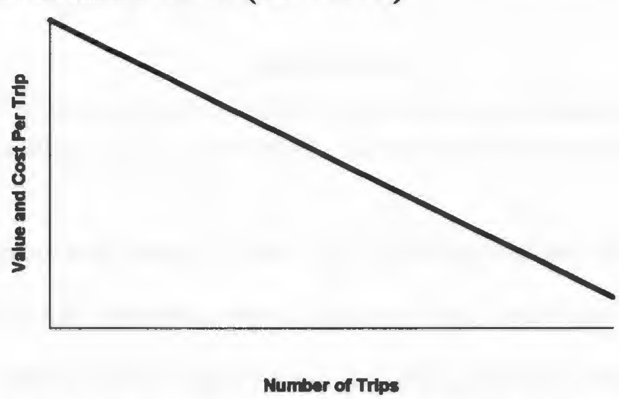


The trips you take vary in importance. Some trips you will take only if your cost (including financial, time and discomfort) is low.

[5] For example, a price elasticity of driving with respect to fuel of -0.5 means that a 1% increase in fuel induces a 0.5% reduction in driving.

If you create the same type of graph for an entire community it would include thousands or millions of potential trips, as shown in Figure 5-2. This is a travel demand curve. It would typically be a more-or-less straight line, indicating a relatively consistent sensitivity of consumption (travel) to users' costs.

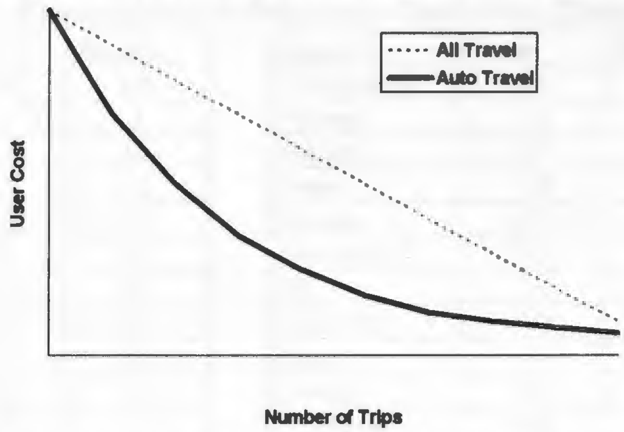
Figure 5-2 **Travel Demand Curve (All Travel)**



Considering all trips made in a community, some have higher value to users than others.

A demand curve for just *automobile* trips will look somewhat different. Rather than being a straight line it is typically concave, indicating a higher sensitivity to price, as shown in Figure 5-3. Why? Because if the price of driving increased, users can either forego the trip *or* take another mode. If the price of driving decreased, it would increase total trips *and* attract trips from other modes. These two effects are additive. In general, the more narrowly a good is defined the more concave its demand curve because consumers have more alternatives. For example, the demand curve for *peak period automobile trips along a certain corridor* would be even more sensitive to price changes (more convex) since users can change their amount of travel and shift trips to other routes, times or modes.

Figure 5-3 **Travel Demand Curve (All Travel and Auto Travel)**



Automobile travel is more sensitive to cost changes than travel taken as a whole, because users can shift to and from other travel modes. This results in a concave demand curve.

Elasticities depend on several factors. Some trips are price inelastic because they are highly valued and users may have few travel choices, while others are quite sensitive to price either because the trip itself is discretionary or because there are substitutes, which can include alternative destinations, times and modes. Transport overall is a major portion of most household budgets, which implies high elasticity, but many costs are fixed, so the user's marginal cost of any one trip may be small, reducing their elasticity.

Elasticities are affected by time.[6] In the short term about the only way consumers can reduce their fuel consumption is by eliminating trips and shifting destinations when possible, or using existing travel alternatives. In the medium term they can also buy more efficient cars and choose housing and job locations that require less driving. In the long term additional land use and transport changes can occur that reduce automobile dependency. Thus, it may take many years for the full effect of a price increase to be felt. Short term is typically less than two years, medium term is two to 15 years, and long term is 15 years or more, although definitions vary. Large price changes tend to be less elastic than small price changes, since consumers make the easiest accommodations first.

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[6] J.M. Dargay and P. B. Goodwin, "Estimation of Consumer Surplus with Dynamic Demand Changes," in *Proceedings of European Transport Forum*, PTRC, Sept. 1994.

Table 5-1 **Long Run (>15 years) Petroleum Elasticities (Sterner et al., 1992)**[7]

Country	Price	Income
Canada	**-2.0**	**0.5**
USA	**-1.2**	**1**
Austria	-1.2	1.2
Belgium	-1.5	1.3
Denmark	-0.8	0.7
Finland	-1.2	1.3
France	-0.4	1.2
Germany	0.1	0.5
Greece	0.2	2.0
Ireland	-1.0	0.9
Italy	-0.7	1.3
Netherlands	-3.2	0.6
Norway	-2.5	1.3
Portugal	-0.7	1.9
Spain	-1.2	2.1
Sweden	-0.1	1.2
Switzerland	0.2	1.5
UK	-1.4	1.5
Australia	-0.2	0.7
Japan	-0.3	0.8
Turkey	-1.1	1.3
Mean	**-1.0**	**1.2**

In the long run fuel consumption is quite sensitive to changes in price and user income.

Goodwin estimates the price elasticity of gasoline at -0.27 in the short term and -0.7 in the long term, meaning that a 10% increase in fuel price reduces fuel consumption by 2.7% in the short term and 7% in the long term.[8] Dargay reports higher values averaging -0.67 when price increases and decreases are calculated separately.[9] Sterner et al. find long run North American fuel elasticities to be greater than 1.0, as shown in Table 5-1. Kågeson cites studies indicating that the elasticity of fuel is -0.2 to -0.3 in the short run, and -0.8 to -1.0 in the long run, most of which results from increased fuel efficiency.[10] Schipper and Johansson estimate vehicle ownership, use and fuel consumption elasticities.[11] They conclude that the long run elasticity of driving with respect to fuel price is -0.3.

John DeCicco and Deborah Gordon conclude that the medium-term elasticity of motor vehicle fuel in the U.S. is probably -0.3-0.5.[12] They point out that CAFE standards have artificially increased U.S. fleet vehicle efficiency enough that consumers are unlikely to

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[7] Sterner, Dahl, Frazen, "Gasoline Tax Policy, Carbon Emissions and the Global Environment," *Journal of Transport Economics and Policy*, 26/2, p. 109-119, Cited in Works Consultancy, 1993.

[8] Goodwin, "Review of New Demand Elasticities," *Journal of Transport Economics*, May 1992, p.157.

[9] Joyce Dargay, "Demand Elasticities," *Journal of Transport Economics*," January 1992, p. 89.

[10] Per Kågeson, *Getting the Prices Right*, European Fed. for Transport & Env., 1993, p.175.

[11] Lee Schipper and Olof Johansson, *Measuring Long-Run Automobile Fuel Demand*, TRB Annual Meeting (Washington DC), Paper #950168, January 1995.

[12] DeCicco and Gordon, *Steering with Prices: Fuel and Vehicle Taxation and Market Incentives for Higher Fuel Economy*, American Council for an Energy Efficient Economy (Washington DC), Dec. 1993.

respond significantly to small increases in fuel prices, such as an additional $0.05 per gallon tax. They refer to this as a "rebound" effect, because increasing fuel efficiency reduces users' marginal costs, encouraging more driving and reducing the effect of fuel price hikes on consumption.

Table 5-2 **Elasticity Estimates for Various Trips Types** [13]

Trip Type	Elasticity of Road Travel with Respect to Out of Pocket Expenses
Urban shopping	-2.7 to -3.2
Urban commuting	-0.3 to - 2.9
Inter-urban business	-0.7 to -2.9
Inter-urban leisure	-0.6 to -2.1
Freight	-0.6 to -2.0

These are elasticities of *fuel use* with respect to fuel price. Although the major *variable financial* cost of driving, fuel accounts for only about 15% of users' financial costs. It is therefore not surprising that vehicle use does not decrease significantly in response to moderate change in fuel prices, since this only represents a very small change in total user costs. Increased fuel prices will cause a combination of reduced driving and increased fuel efficiency (especially in the long run).

Our concern is with motor vehicle use, not just fuel consumption. Kenneth Button's elasticity estimates of driving with respect to *user out of pocket expenses* for various types of trips show relatively high values, Table 5-2. Oum, et al. estimate the elasticity of automobile use with respect to *overall price* is -0.23 in the short run and -0.28 in the long run, with a wide range of variations.[14] Although most discussions of travel elasticities focus on financial costs, reductions in congestion and other transport improvements that save travel time typically increase travel and attract shifts from other modes, which

[13] Button, *Market and Government Failures in Environmental Management*, OECD (Paris), 1992, p.53.
[14] Tae Hoon Oum, W.G. Waters II, and Jong-Say Yong, "Concepts of Price Elasticities of Transport Demand and Recent Empirical Estimates, *Journal of Transport Economics*, May 1992, pp. 139-154.

indicates the elasticity of driving with respect to time costs. Similar elasticities exist for comfort and probably prestige, although there is little quantified data on these.

Table 5-3 **Estimated Elasticities of VMT with Respect to User Cost[15]**

Cost Component	Short Run Effect	Long Run Effect
Out-of-Pocket Price		
Fuel (work)	- Low	- Low to Medium
Fuel (non-work)	- Medium	- Medium to High
Highway tolls	- Medium	- High
Parking fees	-Low	- High
Time Costs		
Riding time	- Low	- Medium
Parking search	- Low	- High
Congestion	- Low	- High
Cost of Alternatives		
Transit fare	+ Low	+ Low
Transit access time	+ Low	+ Low

Elasticities: Low = 0 to 0.5; Medium = 0.5 to 1.0; High = 1.0+

Terry Moore and Paul Thorsnes indicate that driving and other transportation activities are relatively elastic when properly measured, especially in the long run, shown in Table 5-3. The Australian Road Research Board publishes travel elasticity estimates in shown in Table 5-4.

Table 5-4 **Australian Travel Demand Elasticities[16]**

Elasticity Type	Short-Run	Long-Run
Petrol consumption and petrol Price	-0.12	-0.58
Travel level and petrol price	-.10	
Bus demand and fare	-0.29	
Rail demand and fare	-0.35	
Mode shift to transit and petrol price	+0.07	
Mode shift to car and rail fare increase	+0.09	
Road freight demand and road/rail cost ratio	-0.39	-0.80

[15] Terry Moore and Paul Thorsnes, *The Transportation/Land Use Connection*, American Planning Association (Chicago), Report #448/449, Washington DC, 1994, Appendix B.
[16] James Luk and Stephen Hepburn, *New Review of Australian Travel Demand Elasticities*, Australian Road Research Board (Victoria), December 1993.

Transportation modelers have developed elasticity coefficients for various cities and trip types that include vehicle access time (both walking and waiting), vehicle travel time, vehicle costs, and parking costs.[17] Greig Harvey summarizes a variety of transport elasticity estimates, including toll prices, fuel taxes, transit fares, and parking pricing.[18]

Since fuel represents about 15% of total vehicle costs, a -0.2 elasticity of driving with respect to fuel prices represents an elasticity of -1.4 with respect to the total financial costs of driving. In other words, if all user costs were converted into a single variable charge, current fuel price elasticities imply that a 1% increase in this user charge would reduce driving by -1.4%. This implies a relatively high degree of elasticity.

The hypothesis that driving is actually relatively elastic with respect to total user charges is further supported by elasticity estimates of driving with respect to parking price. Shoup and Willson found that charging employees for parking tends to reduce solo commuting by 20-40%. They estimate the employee parking elasticity of demand at -.16,[19] which means that a 10% increase in parking charges reduces employee SOV commuting by 1.6%. Assuming a $30 average monthly parking fee and average monthly user costs of per automobile of $380, a -.16 elasticity of employee parking implies a total price elasticity of about -2.0 with respect to total user financial costs of driving.

Research indicates that cross elasticities between driving and other travel modes are highly sensitive to land use patterns, transit service quality, and the ease of walking and bicycling.[20] Increased urban density, improved pedestrian facilities and transit service, and increased prices for driving are estimated to have a greater effect on reducing VMT when

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[17] Travel Model Improvement Program, *Short-Term Travel Model Improvements*, Technology Sharing Program, USDOT (Washington DC), 1994, Table 7.1 & 7.2.
18 Greig Harvey, "Transportation Pricing and Travel Behavior," *Curbing Gridlock*, National Academy Press, 1994.
[19] Donald Shoup, "Employer-Paid Parking," *Transportation Quarterly*, April 1992, 46/2, p. 172.
[20] See research publications by LUTRAQ program, 1000 Friends of Oregon (Portland).

implemented together than each could have individually. According to one estimate, automobile user costs would have to rise 300% to reduce VMT by 33%, but if accompanied by density increases near transit, better transit speeds, and traffic congestion, pricing would have a much greater effect.[21] Robert Johnson and Raju Ceerla state,

> *"Since the work trip is so unresponsive to price increases (demand is inelastic), good transit service to work centers was found to be needed...Increased auto operating costs per se was found to increase transit travel to work in the various regions, especially if good radial service (to the urban center) was simulated.*[22]

The actual synergetic effects of these factors are currently uncertain, but elasticity estimates in Table 5-5 are probably the lower bound where effective land use and TDM programs are implemented, and an upper bound where no such efforts are made.

Table 5-5 **Best Guess Elasticity of VMT With Respect To User Prices**

Time Period	Fuel Prices	Total User Financial Costs
< 1 year	-0.1	-0.5
1-15 year	-0.4	-1.0
> 15 year	-0.5	-2.0

Elasticity estimates are useful for analyzing and predicting potential impacts of price changes. Actual effects depend on the availability of alternatives and other factors.

An understanding of travel elasticities is useful because pricing can be used to manage transport. Elmer Johnson states, *"As people begin to pay the full social costs of driving, they would take greater care in deciding when and how to move from place to place. Solo travel would decrease substantially."*[23] There is considerable interest now concerning the potential of pricing to encourage more efficient travel patterns, the economic and social impacts of increased prices, and the best way to implement such strategies.

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[21] Webster, Bly and Paulley, *Urban Land-Use and Transportation Interaction: Policies and Models*, Avebury (Brookfield, MA), 1988, cited in "Effects of Land Use Intensification and Auto Pricing Policies on Regional Travel, Emissions and Fuel Use" draft report by Robert Johnston and Raju Ceerla, 1994.

[22] "Effects of Land Use Intensification and Auto Pricing Policies on Regional Travel, Emissions and Fuel Use," draft report by Robert Johnston and Raju Ceerla, 1994, p.6.

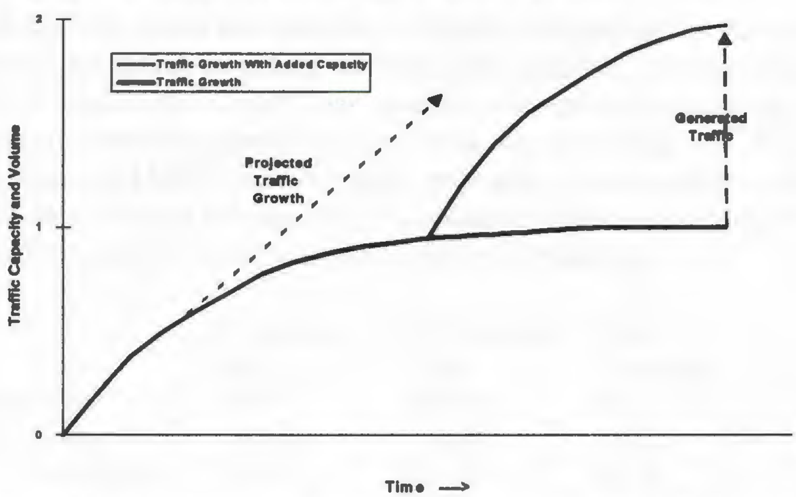
[23] *Avoiding the Collision of Cities and Cars*, American Academy of Arts and Sciences, 1993, p. 43.

5.3 Defining Generated Traffic

Generated traffic is the additional travel resulting from a transport improvement which would not otherwise occur (Figure 5-4). The existence of generated traffic is proven both theoretically and empirically.[24] It is recognized by economists, urban planners, and traffic modelers (who call it *feedback*). Generated traffic results from latent travel demand constrained by user costs (vehicle expenses, travel time, discomfort and risk) caused by poor roads and traffic congestion. A reduction in these costs can induce more travel.

If roads are congestion residents tend to defer trips that are not urgent, and forego trips that can be avoided. For example, when choosing where to go for dinner or shopping, you may consider a wide range of destination when traffic flows freely, but limit yourself to nearby destinations if roads are congested. In some situations you may even choose to walk, bicycle or take transit rather than fight traffic to reach your destination.

Figure 5-4 **Affect of Road Capacity on Traffic Volumes**



Traffic grows quickly after a road is built, then the growth rate declines as congestion develops. A demand projection made during the high growth period indicates the need for more capacity, but this need declines as congestion becomes self-limiting. If capacity is added, traffic growth continues until it is filled. This is called "generated traffic."

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[24] Mark Hansen, et al., *Air Quality Impacts of Urban Highway Capacity Expansion: Traffic Generation and Land Use Changes*, Institute of Transport Studies, University of California (Berkeley), Research Report UCB-ITS-RR-93-5, 1993; SACTRA 1994; Terry Moore and Paul Thorsnes, *The Transportation/Land Use Connection*, American Planning Association (Chicago), #448/449, 1994.

Generated Traffic Example

A person must deliver a package 10 kilometers across town (20 km round trip). Her driving time is worth $10 per hour. Her marginal vehicle costs are $0.10 per km under free flowing conditions and $0.15 under congested conditions. When the roads are congested the trip takes 60 minutes. When the roads are uncongested the trip takes 30 minutes. Her alternative is to mail the package at the local post office, which takes 15 minutes on average walking and waiting in line, and costs $5.00, or a total cost of $7.50. As long as the cost of mailing is greater than the cost of driving she will make the cross town trip. In this case she would choose to deliver it herself if the road is uncongested, saving $0.50, but would mail it if the road is congested, saving $5.50 in total costs.

Total User Costs	*Congested Trip*	*Uncongested Trip*	*Mail Package*
Time cost @ $10.00/hr	$10.00	$5.00	$2.50
Postage cost	0.00	0.00	5.00
Vehicle cost	3.00	2.00	0.00
	$13.00	$7.00	$7.50

A congestion reduction project could generate this trip by making personal delivery cheaper than mail. Users' potential net benefits range from $0 to $6.00, with an average of $3.00. This reflects the Rule-of-Half, which states that net benefits of generated travel are approximately half of total time saving benefits.

The generated trip also incurs external costs, including congestion on roads other than the one being considered for improvement, air and noise pollution, parking requirements, increased energy consumption, road wear, accident risk and reduced travel options for non-drivers. Assume that the average total external cost of driving is $0.50 per mile under congested condition and $0.25 per automobile mile under uncongested conditions, and that the mail truck carries an average of 1,000 packages, imposes costs double an automobile, and requires 20 miles of travel to deliver the package.

Total costs	*Congested Trip*	*Uncongested Trip*	*Mail Package*
Internal Costs	$13.00	$7.00	$7.50
External Costs	10.00	5.00	0.02
Total Costs	$23.00	$12.00	$7.52

The total cost of driving is higher than the total cost of mailing the package under either level of congestion. While it is possible that some generated trips substitute for activities that have even greater external costs than driving, this is unusual since driving has higher external costs than most other activities. Generated traffic can also have long term effects. For example, if enough residents shift from mailing to delivering packages by car the local post office may close due to low use, increasing mailing costs, which imposes extra burdens on non-drivers who depend on it.

The term *generated traffic* has two somewhat different meanings depending on the perspective. Traffic planners and engineers are primarily concerned with traffic generated *on a particular road or corridor* since it affects their efforts to improve traffic flow. Policy makers and economists are concerned about increases in *total vehicle travel* because it affects total costs. As discussed in the next section, some of the traffic that appears on an improved roadway is actually diverted from other routes and times and does not reflect increased driving. The emphasis in this chapter is on overall motor vehicle travel, but generated traffic on improved roadways is also considered.

In the short term, most of the increase in traffic that occurs on an improved road results from trips that are *diverted* from other routes, travel times and modes. Downs calls this *Triple Convergence*.[25] Over the long term structural changes including land use changes (sprawl, and agglomeration of services), increased automobile ownership, and reduced transport choices that result in more and longer automobile trips. These individual changes can have synergetic effects called *automobile dependency*.[26]

5.4 Types of Generated Traffic

Road improvements produce several different effects which increase traffic on a particular road, as described in Table 5-6. These distinctions are important because different types of generated traffic tend to have different impacts and costs. Although all increase traffic on an improved road, some have less net cost than others. In general, *diverted automobile trips* have little incremental costs because they simply change the route or time of an existing automobile trip. *Longer trips* have moderate incremental costs. *Increased automobile trips* have the largest incremental costs. Some types of generated traffic also impose secondary costs by encouraging land use changes (such as sprawl) and transport system changes (such as reduced public transit service and pedestrian facilities) that

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[25] Anthony Downs, *Stuck in Traffic*, Brookings Institute (Washington DC), 1992.
[26] Peter Newman and Jeff Kenworthy, *Cities and Automobile Dependency*, Gower (Aldershot), 1989.

increase travel needs, increase automobile ownership, and reduce affordable travel alternatives. These increase automobile dependency and have negative equity impacts by making non-drivers and poor people relatively worse off, as discussed in chapters 3.9 and 3.14.

Table 5-6 **Traffic Effects of Roadway Improvements**

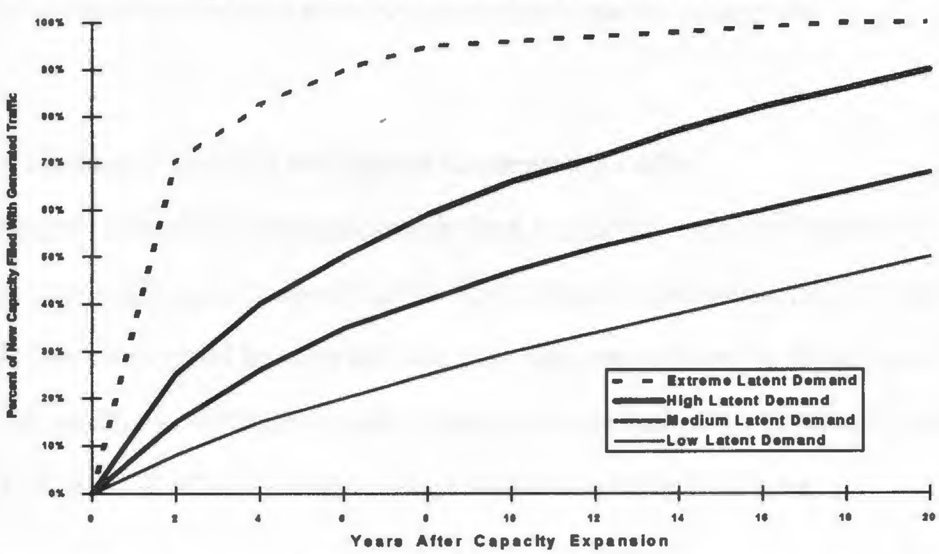
Name	Description	Type of Change	Time Frame	Travel Impacts	External Cost Impact
Shorter Route	Improved road allows drivers to use more direct route.	Diverted trip.	Short term	Reduction	Reduction
Longer Route	Improved road attracts traffic from other, more direct routes.	Longer trip.	Short term	Small increase	Slight increase
Time Change	Reduced peak period congestion reduces the need to defer trips to off-peak periods.	Diverted trip.	Short term	None	Moderate increase
Mode Shift; No Capital Changes	Improved traffic flow makes driving relatively more attractive than other modes.	Diverted trip, generated auto trip.	Short term	Increase	Moderate to large increase
Mode Shift; With Capital Changes	Less demand leads to reduced rail and bus service, reductions in bicycle and pedestrian facilities, and more automobile ownership.	Diverted trip, generated auto trip.	Long term	Increased driving, reduced alternatives.	Large increase, with equity costs.
Destination Change; Current Land Use	Reduced travel costs allow drivers to choose farther destinations. No change in destination locations.	Longer trip.	Short term	Increase	Moderate to large increase
Destination Change; Land Use Changes	Improved access allows land use changes, especially urban fringe development.	Longer trip.	Long term	Increased driving, automobile dependent land use	Moderate to large increase, with equity costs.
New Trip; No Capital Changes	Improved travel time allows driving to substitute for non-travel activities.	Generated trip.	Short term	Increase	Large increase
New Trip; With Capital Changes	Improved access increases activities that require driving, reduced alternatives to driving.	Generated trip.	Long term	Increased driving, automobile dependency.	Large increase, with equity costs.
Automobile Dependency	Synergetic effects of increased automobile oriented land use and transportation system.	Generated trip.	Long term.	Increased driving, few alternatives.	Large increase, with equity costs.

This table describes various traffic effects of road improvements. Some are diverted trips while others are generated travel. All increase traffic on the improved roadway.

5.5 Predicting Generated Traffic

A recent University of California study calculated elasticities of vehicle traffic with respect to road capacity to be 0.15-0.3, 0.3-0.4, and 0.4-0.6 for 4, 10, and 16 years respectively,[27] meaning that up to 60 of each 100 additional roadway spaces are filled with generated traffic within 16 years. The researchers state that higher rates of traffic generation are likely in many urban areas due to increased latent demand. Kenneth Small cites research indicating that 50% to 80% of increase in highway capacity is soon filled with generated traffic.[28] Figure 5-5 shows the likely range of generated traffic on an improved highway.

Figure 5-5 **Elasticity of Traffic Volume With Respect to Road Capacity[29]**



This shows expected generated traffic on a road after its capacity increases. About half of added capacity is filled with new traffic within a decade of construction, and even more traffic can be generated on extremely congested roads.

This research indicates that about half of new road capacity is typically filled with new trips that would otherwise not have otherwise occured within a decade of construction. In

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[27] Mark Hansen, et al., *Air Quality Impacts of Urban Highway Capacity Expansion: Traffic Generation and Land Use Changes*, Institute of Transport Studies, University of California (Berkeley), Research Report UCB-ITS-RR-93-5, 1993.
[28] Kenneth Small, *Urban Transportation Economics*, Harwood (Chur), 1992, p. 113.
[29] Based on Hansen, et al. and comments by Professor Robert Johnston.

areas with extreme latent demand half of the added capacity can be filled with generated traffic within two years, and nearly all of the added capacity may be filled after 20 years.

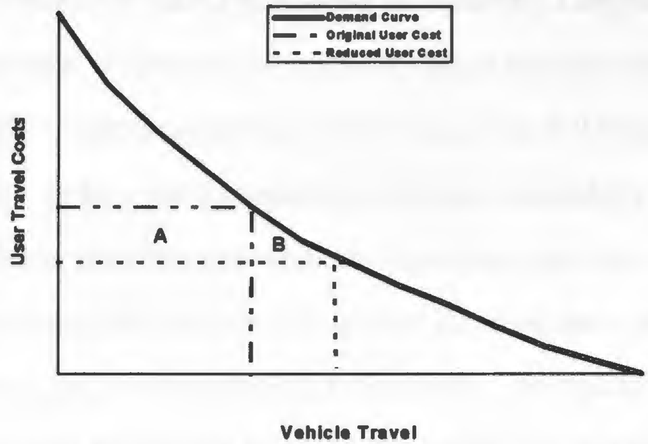
These elasticity estimates refer only to traffic increases on the improved road. Some of this traffic increase results from diverted trips and does not represent a total increase in vehicle travel. One type of generated traffic (*Shorter Route* in Table 5-6) actually reduces vehicle travel and external costs. But such savings are overwhelmed by generated travel, causing net increased vehicle travel and external costs. The University of California team found that total vehicle travel increased 1% for every 2% to 3% increase in highway lane miles. This supports the hypothesis by Newman and Kenworthy that automobile oriented transport and land use policies increase automobile dependency and use.

5.6 Calculating Internal Benefits of Generated Traffic

Most transport benefit/cost manuals specify how to calculate net user benefits of generated traffic using the Rule-of-Half.[30] This states that generated traffic consists of relatively low value travel because they are trips that users choose to forego under more congested conditions. Their net benefit is assumed to be half of the benefit for existing trips. The Rule-of-Half is illustrated using a demand curve in Figure 5-6.

[30] See for example, *Manual on User Benefit Analysis of Highway and Bus Transit Improvements*, AASHTO, 1977, p.26; *COBA Manual*, British Dept. of Transport (London), 1989 Reprint, p. 1-15.

Figure 5-6 **Vehicle Travel Demand Curve Illustrating the Rule-of-Half**



A reduction in user costs (downward shift on Y axis) increases vehicle travel (rightward shift on X axis). Rectangle A shows the benefits of reduced user costs for existing trips. Triangle B shows the benefits of generated traffic.

For example, if there are 100 possible peak period automobile trips on a road but only room for 75, travelers must forego 25 trips due to congestion delays. The foregone trips are those users consider less valuable than the trips they take. If roadway capacity increases, the 25 new trips are relatively low value. Economists estimate that net benefits of generated traffic average half the benefit to existing travelers (illustrated in Figure 5-6 by the fact that B is a triangle rather than a rectangle) and call this the *Rule-of-Half*.

5.7 Calculating External Costs of Generated Traffic

Driving imposes a number of external costs, as described earlier. Urban peak period driving, the type of driving most likely to be generated by increased road capacity, usually has the highest external costs. Net external costs should be charged as costs of a project that induces generated traffic, with the exception of congestion on a route being considered for capacity expansion to avoid double counting delay costs. The contribution of generated traffic to congestion on other roads *should* be considered a cost of the project that creates it.

To illustrate this, consider the effects of building or expanding a highway into a city's downtown. If the number of automobile trips don't change the improved highway would simply benefit travelers without increasing external costs. But if the highway generates new automobile trips, surface street congestion, pollution and parking problems (costs) in downtown will increase. Alternative investments (transit service, bicycle lanes or a TDM program) can provide mobility to downtown without incurring these costs. In order to accurately assess and compare these potential investments, the additional external costs of the generated traffic must be included as a cost of the highway project.

Determining net external costs of driving requires subtracting the external cost of the trip alternative (the activity that would occur without the policy, program or project under consideration). In the case of diverted traffic this is the difference in external costs between the two trips. For longer trips this is the increase in externalities over the shorter trip. For generated travel this is the external cost difference between the trip and the non-travel activity that it replaces. There is no specific research on the external costs of activities that generated traffic substitutes for, but since driving has greater social and environmental impacts than most other activities people typically engage in, we can assume that such costs are overall significantly lower than driving.

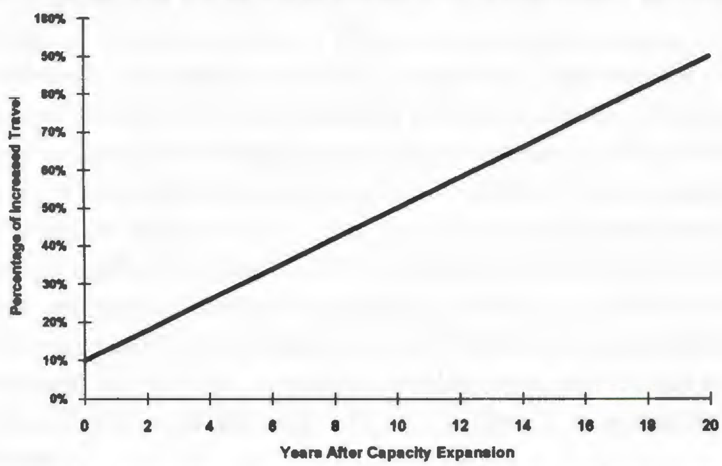
Roadway improvements that induce mode shifts may also result in diseconomies in transit service, which should also be considered costs.[31] Adding road capacity is increasingly expensive in most urban areas due to rising land acquisition costs and community resistance. Failure to consider these increasing marginal cost (for example, by estimating congestion costs based on previous rather than future road construction costs or ignoring increases in transit service costs) further understates the total costs of generated traffic.

[31] H.C.W.L. Williams, et al. "Transport Policy Appraisal with Equilibrium Models III: Investment Benefits in Multi-Modal Systems," *Transportation Research B*, Vol. 25, No 5, pp. 293-316, 1991. Also see John Kain, "Impacts of Congestion Pricing on Transit and Car Pool Demand and Supply," in *Curbing Gridlock*, TRB, National Academy Press (Washington DC), 1994, pp. 502-553.

Short and Long Term Effects

As described in Table 5-6, short term generated traffic consists primarily of diverted trips. Longer trips, generated trips and increased automobile dependency tend to be long term effects. Most short term changes probably occur within about a year of capacity expansion since they only require users to change their habits and do not involve significant changes in land use or transit service provisions. Eventually generated trips will crowd out some of the diverted traffic, since the improved road offers increasingly less relative advantage over other routes. For example, if one year after a road project is completed there are 400 additional peak period trips, these can be assumed to be primarily diverted. If, after 10 years there are 1,200 additional peak period trips, somewhat less than 400 of these (say 200) result from diverted traffic and the rest are new trips resulting from land use changes and increased automobile dependency.

Figure 5-7 **Increased Travel as a Percentage of Generated Traffic on a Roadway**



This graph estimates the portion of travel that is generated rather than diverted.

The distribution of different types of generated traffic over time is an important subject that has received little research. One recent survey estimates that short term generated traffic increases travel only 3-5%, indicating that it consists mostly of diverted trips.[32] Figure 5-7 shows the likely distribution of generated traffic between diverted and generated trips, based on the assumption that diverted trips are initially the major source of increased traffic on an improved road, but over a 20 year time period generated travel (new and longer trips) increase and eventually dominate.

There is currently no standard procedure for calculating the net cost of generated traffic. In order to help develop useful working estimates, what we do know about generated traffic costs is summarized below:

1. Net costs are calculated by subtracting the cost of the trip alternative, which may be a different trip or a non-travel activity.

2. Net costs depend on the type of generated traffic, as described in Table 5-6. This shows that only one type (shorter routes) reduces costs. Of the rest, two divert automobile trips and tend to have small net costs, three lengthened trips and have moderate net costs, and four generate new automobile trips and have large net costs.

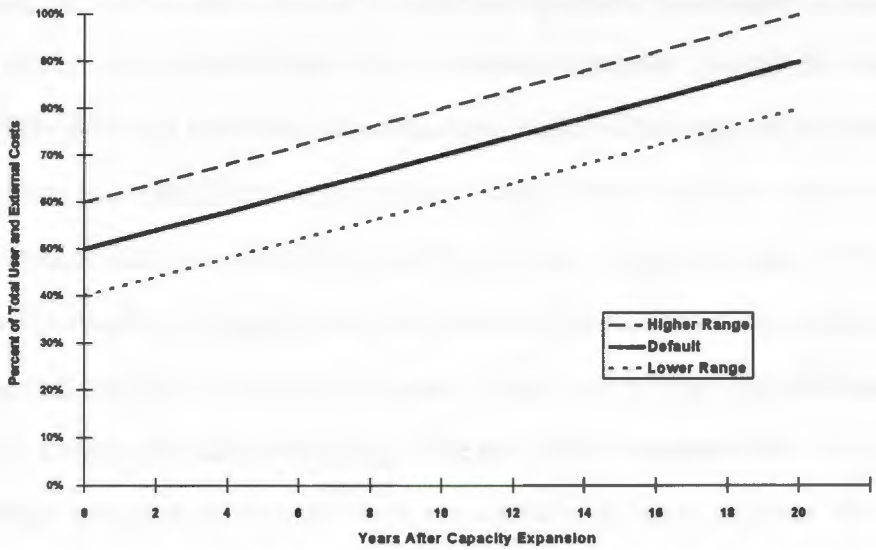
   Total costs of generated traffic can be greater than the direct external costs of individual trips as a result of indirect effects on alternative modes and land use.[33] This can be illustrated by an example in which a highway improvement results in the abandonment of parallel rail service due to reduced ridership. The net external costs of the project include the external costs of the generated traffic plus the incremental external costs of any reduction in rail service resulting from reduced demand, including driving on other roads. In this way the road improvement may increase overall regional traffic congestion. Such an situation is unlikely to occur in North America now, simply because few communities still have viable rail service, but a similar effect may result from other impacts of increased automobile dependency, including reduced bus service, sprawled development, and loss of local services such as neighborhood shops and schools, all of which result in increased overall automobile use.

3. Net costs as a portion of total costs tend to increase over time because to the increasing portion of generated tips. Although the *effects* of automobile dependency are largely long term (such as increased sprawl and reductions in the availability of

[32] Richard Dowling and Steven Colman, *Effects of Increased Highway Capacity: Results of a Household Travel Behavior Survey*, TRB Annual Meeting (Washington DC), #950409, January 1995.
[33] H.C.W.L. Williams, et al. "Transport Policy Appraisal with Equilibrium Models III: Investment Benefits in Multi-Modal Systems," *Transportation Research B*, Vol. 25, No 5, pp. 293-316, 1991.

alternative modes), the *causes* occur as soon as land and transportation investment decisions are influenced.

Figure 5-8 **Estimated Net Costs as Percentage of Generated Traffic Total Costs**



Since generated traffic tends to result more from diverted trips in the short term and generated travel over the long term, net costs as a portion of total costs increase over time. This graph is a multiplier for estimating net external costs.

Based on these assumptions, net generated traffic costs are estimated to be 40-60% of total external costs in the short term, and increase to 80-100% over the long term, using a 20 year planning horizon. Figure 5-8 illustrates a proposed default multiplier that can be used to estimate net external costs for planning purposes.

5.8 Land Value Impacts

Road improvements can lead to land use changes that affect real estate values. This occurs because transport is used to compete for desirable locations. For example, people often face tradeoffs between travel and location costs: lower priced urban fringe land requires more driving. Road improvement benefits are captured as increased vehicle operating costs (due to longer trip distances), consumer surplus (commuters can purchase more land at a lower cost than would be possible closer to the urban center) and producer surplus (profits to urban fringe land owners). Sometimes communities compete for economic development by offering transport facility subsidies. Such subsidies can also capture a portion of transport improvement benefits.

Competition for access can create a self-perpetuating cycle of increasing costs, since increased motor vehicle traffic degrades the urban environment, thereby increasing the desire by individuals for exurban residences. Both increased driving and increased development at the urban fringe impose external costs. This creates a "social dilemma" in which individuals' short term interests conflict with their long-term interest.[34] The tendency of increased travel speeds to result in dispersed destinations, no reduction in travel time, and increased overall travel costs, is described as *space pollution* and *time pollution* by Geographer John Whitelegg.[35] He and other researchers find that the amount of time people spend on travel varies little, regardless of speed or mode of travel. Increased travel speeds often result in increased travel, not more free time. He writes,

> *"Those who use technology to travel at greater speeds still have to make the same amount of contacts--still work, eat, sleep and play in the same proportions as always. They simply do these further apart from each other."*

In economic analysis it is important to include the cost of all public subsidies and to exclude any benefits associated with increased real estate values in order to avoid double counting. Some transportation investment economic analysis models such as MEPLAN and TRANUS track land value benefits, but exclude travel time savings for this reason.

5.9 Applying Generated Traffic External Cost Estimates

There has been little research on the subject of calculating net costs of generated traffic and even less to develop practical tools for incorporating these costs into common transportation decision making such as evaluation of particular transport plans, projects or

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[34] Emin Tengstrom, *Use of the Automobile*, Swedish Transport Research Board (Stockholm), 1992, p. 59. Also see Garret Hardin, "Tragedy of the Commons," *Science Magazine*, Dec. 1968, pp. 1243-1247.
[35] John Whitelegg, "Time Pollution," *The Ecologist*, Vol. 23, No. 4, July/Aug. 1993, p. 131-134.

policies. This is an unfortunate omission because this cost has significant implications in such decisions. The current practice of ignoring generated traffic overstates the benefits of increasing road capacity and understates total costs, which tends to skew decisions toward automobile dependency and away from other transportation options.[36]

Generated traffic can be incorporated into transport planning in three ways:

1. *Roadway capacity.*

   Total increased motor vehicle travel that would result from expanding capacity on a roadway can be calculated using the elasticity estimates illustrated in Figure 5-5. Incorporating generated traffic is important to accurately determine travel time savings, user benefits, and external costs. These curves can be used to calculate the effects of generated traffic for each project year to determine accurate net present value. Ideally, each type of traffic effect described in Table 5-6 would be assessed separately, since each has different economic impacts. Figure 5-8 provides a default estimate of net external costs as a portion of total external costs.

2. *Lane mileage.*

   Increasing lane miles increases overall vehicle travel. The travel generated by roadway projects can be estimated using the University of California's research results, indicating that a 1% increase in lane miles increases total vehicle travel by 0.33% to 0.50%.

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[36] H.C.W.L. Williams and W.M. Lam, "Transport Policy Appraisal with Equilibrium Models I: Generated Traffic and Highway Investment Benefits," *Transportation Research B*, Vol. 25, No 5, pp. 253-279, 1991.

3. *Land Use Factors.*

Some land use policies, programs and projects can also generate traffic.[37] Estimates of the relationship between land use density and vehicle travel, such as those by Holtzclaw,[38] and the LUTRAQ project[39] can be use to predict the transportation effect of land use decisions. The conceptual measure of this impact is the *with-and-without* test: the type and amount of development that would occur with and without the transport project.[40]

Since these three approaches for estimating generated traffic overlap in their effects (for example, the elasticity of vehicle travel with respect to road capacity typically incorporates some traffic generated by sprawl), only one of the three should normally be used for evaluating a specific project to avoid double counting.

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[37] Eric Kelley, "The Transportation Land-Use Link," *Journal of Planning Literature*, Vol. 9, No. 2, Nov. 1994, p.128-145; Lawrence Frank, "Impacts of Mixed Use and Density on the Utilization of Three Modes of Travel" paper presented at the Transportation Research Board Annual Meeting, January, 1994; *Reducing Transport Emissions Through Planning*, Dept. of Env. & DoT, HMSO (London), 1993.

[38] John Holtzclaw, *Explaining Urban Density and Transit Impacts of Auto Use*, Sierra Club and NRDC, San Francisco, 1994

[39] Sam Seskin, *The LUTRAQ Project; Travel Behavior*, 1000 Friends of Oregon (Portland), 1994

[40] van Kooten, *Land Resource Economics and Sustainable Development*, UBC Press (Vancouver), 1993.

6.0 Transportation Cost Implications

Consumers and industry face tradeoffs between transport and other costs or benefits. The relative price difference between transport and other goods affects countless decisions such as where to buy a house, where to locate a business, how to distribute the goods that a business produces, and where to go for vacation. These tradeoffs have many indirect impacts. In this chapter the cost estimates developed in this report are used to analyze the implications of transportation costs and underpricing on economic efficiency, economic development, land use, stakeholder perspectives, and travel patterns.

6.1 Economic Efficiency Impacts

A basic tenet of market theory is that economic efficiency is maximized when marginal user prices (defined as *perceived variable internal costs*) reflect total marginal costs. Mispricing causes inefficient use of resources because it prevents users from accurately incorporating costs into their consumption decisions. As one pricing study describes,

> *"Price is the mechanism by which scarce resources are allocated efficiently between competing uses. For consumers, price encourages a purchase if the benefits of making the purchase exceed the benefits of alternatives. For producers, prices provide incentives for resources to move to those uses which people value most highly by informing firms how to produce, which products to produce, when and where to sell the products, and when, where and how to invest."*[1]

According to this study, motor vehicle use is significantly underpriced compared with the costs it imposes on society. External costs are estimated to average 33% of total costs, with a range from 41% for Urban Peak driving to 23% for Rural driving, as shown in Table 6-1. In other words, user costs would need to increase 35% to 72% to incorporate all costs. Other studies described in Chapter 2 reach similar conclusions.

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[1] Halcrow Fox and Associates, *Land Transport Pricing for New Zealand*, Transit New Zealand (Wellington), 1993, p. 47.

Table 6-1 **Average Automobile Costs as a Percent of Total Costs**

	Total Costs	**Internal Costs**		**External Costs**	
Units	**per mile**	**per mile**	**% of Total**	**per mile**	**% of Total**
Urban Peak	$1.32	$0.71	54%	$0.61	46%
Urban Off-Peak	$1.05	$0.71	68%	$0.34	32%
Rural	$0.84	$0.64	76%	$0.20	24%
Weighted Average	*$0.99*	*$0.67*	*68%*	*$0.32*	*32%*

On average, about one-third of the costs of driving are external.

Externalized costs are not the only cause of underpricing. Many vehicle costs are fixed, which further reduces the ratio between prices and total costs. Operating costs (variable financial costs) are only about 35% of users' financial costs, and only about 13% of the total costs of driving. External costs equal 48% to 130% of user marginal costs (vehicle operating costs plus, user time and accident risk), and 181% to 381% of vehicle operating costs. Each dollar spent on gas, maintenance, and short term parking incurs on average $2.61 worth of external costs, including congestion, accident risk, parking subsidies, and environmental degradation. Car owners are "captive" to most costs of driving. We pay fixed and external costs no matter how much or little we drive, which reduces the incentive to limit driving to high value trips. Automobile owners receive only a small portion of the total savings they produce by driving less or more efficiently.

Although underpricing of such a common consumer good may appear beneficial from a narrow perspective (and indeed benefits many individuals in the short term), mispricing reduces overall economic efficiency.[2] Underpriced automobile use increases purchases of transport over other consumer goods, and driving over other travel modes. Low price causes per capita mileage to increase, forcing other constraints, such as congestion, pollution, and resource depletion to limit growth. As Elmer Johnson states,

> *"When a good as central to American life as the automobile remains underpriced for several decades, that good tends to be used more than it otherwise would be. Habits*

[2] Terry Moore and Paul Thorsnes, *The Transportation/Land Use Connection*, American Planning Association, Report #448/449 (Chicago), Washington DC, 1994.

become ingrained and are hard to break. They are reinforced by the present urban infrastructure designed to exploit the full possibilities of private mobility."[3]

External costs are not eliminated, they simply show up elsewhere, for example as higher prices for commercial goods (for parking), increased local taxes (to pay for road services), higher insurance premiums (from automobile accidents), illnesses (from pollution), and lower residential property values (from urban traffic). Another effect of underpriced driving is that non-automotive modes decline. Walking, bicycling, transit, and rail transport receive little capital investment, land use patterns and social habits develop which conflict with these travel options, and they develop a social stigma.

This is not to say that driving would cease if more costs were internalized. Consumers would be willing to pay more for some trips. However, some driving has relatively low value to the user, either because the trip itself provides little net benefit or because reasonable alternatives exist. Increasing prices to reflect a greater portion of total costs would reduce low value driving, improving the transportation system's overall efficiency.

A variety of strategies have been proposed for internalizing costs. A common suggestion is to increasing fuel taxes.[4] This, however, does not reduce all external costs, since fuel prices do not directly affect when or where driving takes place, or provide incentives to buy a low polluting car. Over the long run drivers would buy more fuel efficient cars, which does not reduce congestion, accidents, parking costs, noise or most other environmental impacts. Many countries with fuel prices two or three times higher than in North America experience comparable or greater per capita external costs of driving.[5]

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[3] Elmer Johnson, *Avoiding the Collision of Cities and Cars*, American Academy of Arts and Sciences (Chicago), 1993, p.11.
[4] Steve Nadis and James MacKenzie, *Car Trouble*, WRI, Beacon Hill Press (Boston), 1993, p. 160.
[5] For a comparison see *Victorian Transport Externalities Study; Summary Report*, Environment Protection Authority (Melbourne), Table 3, p.8.

Other analysts emphasize peak hour pricing as a method of internalizing costs.[6] This could reduce congestion but not other externalities such as pollution and parking subsidies.

Underpriced Driving Reduces Transportation Diversity and Efficiency
Underpricing increases automobile dependency and reduces travel choices. These are disadvantages to non-drivers, and may reduce the overall efficiency of the transport system. Harry Dimitriou identifies a "transportation gap" between the 1/2-mile average range of walking, and automobile travel that is inefficient for trips less than about 4 miles due to high per mile pollution, congestion and parking costs.[7] Most urban trips are in this range, which is efficiently handled by bicycles, small low powered vehicles, and local bus service along busy corridors. Dimitriou argues that using automobiles for the relatively short trips common in cities is a "sub-optimal" use of technology that exacerbates urban problems. Underpricing encourages automobile use for trips when more efficient alternatives may be more appropriate.

User charges should be applied as closely as possible to the source of an externality to optimize economic efficiency, although economists and policy makers recognize that in practice a "second best" solution is often necessary.[8] Because of the diverse nature of transport costs no single mechanism can capture all external costs. Charles Komanoff identifies several price changes needed: weight-distance charges, fuel taxes, congestion pricing, smog fees, parking fees, marginalized insurance, and higher fines for violators for optimal efficiency.[9] He estimates that no charge should raise more than 33% of total user revenue for maximum economic efficiency. The Office of Technology Assessment study

[6] Anthony Downs, *Stuck In Traffic*, Brookings Institute (Washington DC), 1992.
[7] H. Dimitriou, *Urban Transport Planning: A Developmental Approach*, Routledge (NY), 1992, p. 245.
[8] This assumes that charges are intended to achieve economic efficiency. If the concern is horizontal equity (its not fair to charge people for goods that somebody else consumes) then a broader range of pricing mechanisms can be considered.
[9] Charles Komanoff, *Pollution Taxes for Roadway Transportation*, Komanoff Energy (NY), 1994

Saving Energy in U.S. Transportation and the European Federation for Transport and Environment reach similar conclusions and recommendations for internalizing costs.[10]

Douglass Lee excludes indirect costs such as pollution embodied in resources consumed in vehicle production and use, arguing that one sector should not be charged for the sins of another sector.[11] Although charging automobile drivers for air pollution produced during steel production or water pollution produced during petroleum distribution may marginally reduce these impacts, it is more effective to apply such charges directly to the steel or petroleum firms in proportion to their external costs as an incentive to reduce such impacts. If pollution costs are simply passed on as surcharges to end users, individual firms have little incentive to minimize the damage they produce. However, until marginal charges are effectively applied it is still legitimate to consider residual impacts an externality of consumption and to charge end users as a second best solution.

It would be inefficient to compensate for externalities so generously that individuals have no incentive to avoid such impacts, as described in the Coase Theorem.[12] For example, it would be a mistake to reward accident victims so well that road users become careless or intentionally cause crashes. Although this argument is sometimes used to justify government inaction on external costs, it seldom actually applies since charging for an externality and compensating victims are separate activities.[13] Rather, it simply means that victim compensation must use common sense to avoid perverse incentives.

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[10] *Saving Energy in U.S. Transportation*, Office of Technology Assessment, 1994. Per Kågeson, *Getting the Prices Right*, European Fed. for Transport & Environment (Bruxelles), 1993, p.154-161.

[11] Douglass Lee, *Full Cost Pricing of Highways*, USDOT National Transportation Systems Center (Cambridge), January 1995, p. 25.

[12] R. Coase, "The Problem of Social Cost," *Journal of Law Economics*, Vol. 3, Oct. 1960, pp. 1-44.

[13] The Coase Theorem states that it may be most efficient to allow producers and victims to negotiate directly for compensation of externalities, provided negotiations are possible and "property rights" are established. In practice, governments must often represent victims' interests and define property rights.

Many costs associated with increasing transportation prices, such as unemployment and reduced profits in motor vehicle dependent industries, are *transition* costs which decrease over time and eventually disappear. Transition costs are the economic inefficiencies that result when capital equipment, policies, contracts and employment become non-optimal due to changes in prices or demand. For example, a business may invest in a market that declines due to higher costs, or choose to purchase a cheaper but less efficient vehicle only to incur losses when fuel prices increase. Similarly, an individual may spend more than expected on commuting if fuel prices increase unexpectedly after they purchase a house that is far from their work site. These result in reduced employment, productivity, and profits in existing sectors (such as new automobile production) until an opportunity occurs to change to more optimal market, equipment or location.

It is tempting to say that these are *"just"* transition costs, but that would be unfair. These are very real costs, both financially and in emotional stress to individuals who lose jobs or receive less pay. But this does not justify underpricing and subsidies. Although automobile industries have traditionally provided economic development and good jobs, it would be a mistake to assume that these benefits are unique to that sector. At best, automobile industries might continue providing current profits and employment, but little growth can be expected due to international competition for markets and increased productivity.

Protecting automobile industries reduces the viability of other industries. Labor and other resources that are currently employed in automobile industries can be more productive in other sectors. Transitions provide benefits by allowing new businesses opportunities and jobs to develop. The economic inefficiency resulting from efforts to protect the North American automobile industry may explain, for example, why the U.S. has failed to succeed in many new industries, such as consumer electronics and manufacturing. A better strategy would be to accept and plan for economic transitions to minimize costs.

6.2 Economic Development Implications of Underpricing

Transport is essential to any economy. It is needed for most economic activities, from production of raw materials, to manufacturing, distribution, supplying labor and professional services. The transport industry is itself a major economic sector. Motor vehicle production, servicing, and use are all major industries, accounting for approximately 17% of GNP, 11% of personal consumption expenditures, and over 10% of total employment in the U.S.[14] As a result, it is often argued that transport investments and low prices encourage economic productivity and development.[15] Increased transport prices are claimed to have a "multiplier effect" that raises overall costs and reduces productivity.[16] Lobbying organizations use these arguments to support underpricing.[17]

Piet Rietveld calls these claims *scientific mythification*. He states that "*...the direct contribution of infrastructure improvement to a reduction in transport costs is in general small in industrialized countries.*"[18] These analyses often ignore total costs and distributional effects. Objective research indicates that transport improvements provide only marginal economic productivity or development benefits.[19] Each dollar of increased revenue to one company resulting from underpricing means a dollar or more of revenue lost elsewhere in the economy.

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[14] American Automobile Manufacturers Association, *Facts and Figures 93*, p. 58; *Transportation In America, 11th Edition, Supplements*, ENO Foundation (Lansdowne). Sept. 1993, p. 4

[15] D. Aschauer, "Is Public Expenditure Productive?" *Journal of Monetary Economics*, Vol. 23, pp. 177-200, 1989; Alicia Mannell, "How Does Public Infrastructure Affect Regional Economic Performance?" *New England Economic Review*, Sept./Oct. 1990, p.11-33; Theresa Smith, "The Impact of Highway Infrastructure on Economic Performance," *Public Roads*, Spring 1994.

[16] Campbell Anderson, "A Business Perspective on Transport Reform" in *Transport Policies For the New Millennium*, Ogden et al. editors, Monash University (Clayton), 1994.

[17] The Allen Consulting Group, *Land Transport Infrastructure: Maximizing the Contribution to Economic Growth*, Australian Automobile Association (Canberra), Nov. 1993.

[18] Piet Rietveld, "Spatial Economic Impacts of Transport Infrastructure Supply," *Transportation Research*, Vol. 28A, No.4, p. 339.

[19] Joseph Berechman, "Urban and Regional Economic Impacts of Transportation Investment: A Critical Assessment and Proposed Methodology," *Transportation Research*, Vol. 28A, No.4, pp. 351-362.

Recent macroeconomic research indicates that transport infrastructure investments may have high economic returns.[20] However, this does not prove that *increased* driving provides economic benefits. Rather, it implies that increased *transport efficiency* provides benefits. Public transit expenditures provide twice the return as highway improvements,[21] indicating that *mobility* rather than just *driving* that provides economic benefits.

Economies and Diseconomies of Scale

The price of a single envelope at my local stationary store is 10¢, but 100 cost only $2.50, offering a 75% per unit savings. This is not surprising because many costs of distributing envelopes are fixed; the same amount of checkout time is taken to sell me one as the box of 100. This is an example of *economies of scale*. Economies of scale also exist with respect to industrial production. Henry Ford's use of mass production to reduce automobile prices, and the recent development of low-cost personal computers are two examples. You benefit if your neighbors consume more of certain goods.

While human production and market activities tend to experience economies of scale, most natural costs tend to experience *diseconomies of scale*. For example, the most suitable land for a given use such as farming will be used first. Providing additional land for the same production requires using less suitable land. Similarly, increasing extraction of natural resources (minerals, fish, timber, etc.) requires using less accessible supplies or more expensive extraction techniques, again incurring diseconomies of scale. Waste disposal can also show diseconomies of scale. Ecosystems can absorb a certain amount of some wastes, but as the volume or rate increases so does the negative impact per unit.

Our economy is increasingly limited by environmental and social constraints that experience diseconomies of scale, while improved logistics and computer controls reduce many of the advantages of large scale production. We cannot expect reduced costs if our neighbors buy more cars and drive more each year, but you will experience increased congestion, pollution, and land use impacts. It is no longer appropriate to encouraging increased production and consumption, especially with respect to transport.

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[20] David Aschauer, *Transportation Spending and Economic Growth*, American Public Transit Association (Washington DC), 1991

[21] 1991, p. 10.

Peter Nijkamp and Eddy Blaas state that transport facility investments only contribute to development if other conditions are ripe and high transport costs are a constraint.[22] Christine Kessides reaches a similar conclusion.[23] She cites studies indicating that infrastructure investments can provide high returns in fast developing countries but only normal returns in developed economies such as North America and Western Europe. These researchers emphasize that regions which already have paved roads, rail, and ports will only enjoy small economic development from marginal improvements in such infrastructure. Since underpricing reduces overall economic and transport efficiency by incurring indirect costs and increasing traffic congestion, it may reduce rather than stimulate overall economic development. Macroeconomic modeling by Arie Bleijenberg indicates that a significant increase in fuel taxes (intended to internalize external costs and reduce travel demand) with revenues used to reduce income taxes would have little overall effect on the Dutch economy, and would slightly increase employment.[24]

Current policies that underprice transportation may have been justified when they were established. The automobile market and road system probably experienced significant economies of scale during the first half of this century.[25] Increased automobile sales allowed manufacturers to reduce production costs, and by distributing construction expenses over more automobile travel, facility costs per VMT declined. This was a unique historical event, however, that does not apply to mature markets. There are probably few, if any, further economies of scale in automobile, petroleum and roadway industries.

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[22] Nijkamp and Blaas, *Impact Assessment and Evaluation in Transport Planning*, Kluwer, 1993, p. 45-49.
[23] Christine Kessides, *The Contributions of Infrastructure to Economic Development*, World Bank Discussion Paper #213 (Washington DC), 1993.
[24] "The Art of Internalising," in *Internalising the Social Costs of Transport*, OECD (Paris), 1994.
[25] Clay McShane, *Down the Asphalt Path*, Columbia University Press, 1994, p. 105. Also see Stephen Goddard, *Getting There*, Basic Books, (NY), 1994

The Effects of Underpricing: Two Industry Example

Consider an economy with two industries: Heavy and Light. Transport is a relatively large portion of Heavy's production costs, and a small portion of Light's.

1. These industries initially face a transport price structure which underprices shipping buy using a property tax to fund roads and other transport costs. Since both industries pay the same tax, Light is effectively subsidizing Heavy.
   Score: Heavy + Light - Economic Efficiency -

2. A $0.10 per mile road use fee is implemented to replace the property tax. Heavy industry pays more taxes, while Light pays less.
   Score: Heavy - Light + Economic Efficiency +

3. At worst, Heavy pays the full road charge. But, Heavy may change shipping practices to reduce costs, so its net cost increase is minimal.
   Score: Heavy = Light + Economic Efficiency ++

4. FairPrice also reduces traffic congestion and accidents. Assume that Heavy industry's shipping time is reduced by 1/2 hour for every 100 miles of trucking and its trucks cost $50 per hour to operate, this means the $10 per hundred mile road user charge saves $25 in operating expenses, for an overall saving to Heavy.
   Score: Heavy + Light + Economic Efficiency +++

Although this example is simplistic, it emphasizes two important points:

1. Underpricing does not eliminate costs it simply transfers them.
2. Full Cost pricing provides economic incentives for business to use resources more efficiently, which provides benefits, especially to transportation dependent industries.

The overall negative economic effects of transport price increases are relatively small, and appear to be declining in most industrial sectors. Transport, especially freight transport has decreased as a percentage of GNP, Industrial Production, and national employment in recent decades due to increased efficiency and more high-value, low-bulk products.[26] Transport accounts for only about 5-6% of most manufactured product prices.[27] Fuel

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[26] *Transportation In America, 11th Edition*, ENO Foundation, 1993, p. 23, and *Supplement*, p. 4.

[27] Diamond and Spence, 1989, quoted in Piet Rietveld, "Spatial Economic Impacts of Transport Infrastructure Supply," *Transportation Research*, Vol. 28A, 1994, p. 337. National Transportation Agency, *An Integrated and Competitive Transportation System*, (Ottawa), March 1992, from *Transportation, Taxation and Competitiveness*, Transport Association of Canada (Ottawa), 1993, p. 56.

taxes are only about 4% of trucking industry gross revenues, and 0.5% of railroad gross revenues,[28] so increased fuel taxes would only have a slight effect on end prices.

Higher vehicle taxes can benefit the economy by reducing traffic congestion, encouraging more efficient shipping patterns, and reducing other taxes, resulting in constant or even declining prices. Because fuel represents a relatively small portion of total industrial costs, Kågeson concludes that, *"The effects from internalizing the social costs of transport on the ability of European industry to compete on the world market will be almost negligible. The total impact will amount to less than 0.5% of the annual turnover of most industries."* and *"GDP costs of a carbon tax may be fully offset by taking advantage of its efficiency value and using the revenues to cut existing taxes that discourage capital formation."*[29] The Office of Technology Assessment considers the possible effects of higher fuel taxes on the U.S. economic development and concludes,

> *"...if a gasoline tax were coupled with an equal-revenue increase in investment tax credits, short-run macroeconomic losses resulting from motor fuel tax increases could be more than offset by the short-run macroeconomic gains".*[30]

A $43.50 per tonne of CO_2 fuel tax (increasing fuel prices 20-30%) on freight transport in Norway is estimated to reduce long-haul rail and truck shipping by 0.26% and 1.82% respectively, local for-hire truck transport would decline only 0.11%, fleet truck shipping would decline 2.08%, and fleet van shipping would decline by 0.36%.[31] The greater reduction in fleet trucks results from their relative inefficiency, since they often travel with part loads, especially on return trips. Over several years these changes would be virtually insignificant compared with normal turnover in these industries.

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[28] *Transportation, Taxation and Competitiveness*, TAC (Ottawa), 1993, p. 25, 29.
[29] Per Kageson, *Getting the Prices Right*, European Fed. for Transport & Env. (Bruxelles), 1993, p. 183.
[30] *Saving Energy in U.S. Transportation*, Office of Technology Assessment, US Congress, 1994, p.225.
[31] Trond Jensen and Knut Eriksen, "A General Equilibrium Model for Freight Transport in Norway," published in *European Transport Forum Conference Proceedings*, PTRC, Sept. 1994.

Table 6-2 **Impacts of Transportation Underpricing**

Better Off	Worse Off
Motor vehicle production, sales and service.	Alternative forms of transportation.
Bulk commodities.	High-value products.
Low-value manufacturing.	Communications and information industries.
Imports.	Domestic and local production.
Isolated companies.	Centrally located companies.
Isolated retail and recreation.	Local oriented retail and recreation.

Internalizing transport costs benefits some companies and harms others. Overall, winners should exceed losers due to overall increased economic efficiency.

Table 6-2 identifies the types of companies that are likely to be better or worse off from underpricing. Only if companies in the "Better Off" category provide higher profits or employment than those in "Worse Off" might underpricing provide overall economic benefit. In fact, the automobile industry has experienced relatively low profits in recent years and its portion of total U.S. employment and industrial production has declined.[32] Similarly, there is no evidence that bulk commodities, low value manufacturing, and isolated commercial and recreation centers are economically more beneficial than the competing industries that are less transportation dependent.

Automobile expenditures provide minimal or negative economic benefits at the regional and local level. Most money spent on new vehicles and parts leaves a community. Fuel purchases make even less contribution to local economies since petroleum products provide minimal local economic activity. A study by Montgomery County, Maryland found that only 15% of gasoline expenditures remained in the regional economy.[33] Even in Los Angeles County, where petroleum is produced and processed, only about 50% of petroleum expenditures stay in the local economy, resulting in an economic multiplier of

[32] American Automobile Manufacturers Association, *Facts and Figures 93*, p. 76. *Transportation In America, 11th Edition, Supplements*, ENO Foundation (Lansdowne), Sept. 1993, p. 4

[33] *Montgomery County Energy Study*, Montgomery Dept. of Env. Protection (Rockville), 1985.

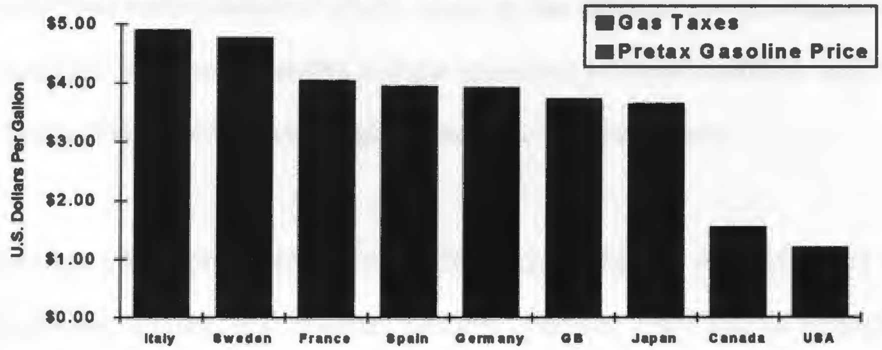
1.8, compared with 2.7 for general goods and services.[34] Thus, reduced driving and increased use of other travel modes can provide local economic benefits.

The relative strength of Asian and European country economies where private automobile use and road investments are much lower further indicates that road building and driving do not directly contribute to economic growth. Walter Hook argues that excessive automobile dependency and use associated with underpriced driving gives the U.S. an economic *disadvantage* relative to Japan.[35] He points out that transport accounts for only 9% of Japanese GNP, about half of the percentage in the U.S. This reduces Japanese industrial and employment costs, increases productivity and frees funds for capital investment. Harry Dimitriou recommends treating intra- and inter-community transport needs separately.[36] It is inter-community (long distance) transport that he believes supports economic development. Marginal improvements to intra-community travel provide little economic benefit in developed regions.

International competition is often used to justify underpricing, but North American fuel prices and user fees are among the lowest among developed nations (Figure 6-1). Our taxes could increase significantly and still be competitive with world markets. Since export industries use only a small portion of U.S. transport, broad underpricing is an inefficient way to support a single sector. A better export stimulation strategy may be to increase domestic prices and use a portion of the revenue to directly support export industries.

[34] L.A. County Transportation Comm., *Transportation Energy Conservation in Los Angeles*, Nov. 1979.
[35] Walter Hook, "Are Bicycles Making Japan More Competitive?," *Sustainable Transport*, Summer 1993; Walter Hook, "The Evolution of Japanese Urban Transportation and Non-Motorized Transport," paper presented at the TRB Annual Meeting, January 9-13, 1994.
[36] Harry Dimitriou, *Urban Transport Planning: A Developmental Approach*, Routledge, 1992, p. 144.

Figure 6-1 **1992 Gasoline Taxes and Prices in Selected Countries**[37]



North America has the lowest fuel taxes and prices among the developed nations.

Transaction costs can make it expensive and therefore inefficient to actually charge marginal prices, which could justify continued underpricing. Direct parking fees and traditional road tolls are a bother because users must deliver money in the correct form, and administrating such fees impose additional costs. People often prefer to reduce transaction costs by paying lump sums or by including such fees in other purchases. This is a legitimate concern, but new technologies significantly reduce transaction costs, lowering the threshold under which marginal pricing is justified. Although transaction costs prevent society from ever achieving pricing that perfectly reflects costs, this is not a barrier to significant progress in marginalizing transport costs.

6.3 External Benefits of Transportation?

Transportation underpricing and subsidies would be justified if there are significant *external marginal benefits* from automobile use. Some lobbying organizations argue that such benefits exist. The Highway Users Federation,[38] the International Road Union, the Deutsche Strassenliga (a German freight organization), and the German Club of

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[37] Pucher and Horschman, "Public Transportation in the United States," *Public Transport International*, Vol. 41, No. 3, Sept. 1993.
[38] Eric Beshers, *External Costs of Automobile Travel and Appropriate Policy Responses*, Highway Users Federation (Washington DC), March 1993.

Automobilists have each published reports arguing that driving provides significant external benefits.[39] Supposed benefits include improved personal mobility, improved economic productivity, and general regional economic development.

These studies have been criticized for methodological problems, such as failure to distinguish between internal and external benefits, counting distributional changes as benefits, and non-marginal analysis.[40] As discussed in the previous section, most indications of economic benefits of driving actually indicate much higher productivity and economic development benefits from more efficient travel modes. That driving provides benefits does not mean that these are external, that *more* driving is necessarily good for society (marginal benefits), that more driving is the best way to improve transportation if other options are available, or that driving should be underpriced.

Significant true external benefits are unlikely because rational consumers tend to internalize benefits and externalize costs, and because external benefits, when they do exist, are quickly captured in economic competition.[41] A 1982 USDOT study concluded, *"the preponderance of expert opinion probably lies on the side of saying that there are no external benefits of highway consumption beyond the benefits to the users."*[42] Two recent studies also conclude that transport benefits, while of great value, are almost entirely internalized and no market failure exists to justify underpricing.[43]

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[39] Cited in Werner Rothengatter, "Do External Benefits Compensate for External Costs of Transport?", *Transportation Research*, Vol. 28A, 1991, p.325.
[40] Per Kageson, *Getting the Prices Right*, European Fed. for Transport & Env. (Bruxelles), 1993, p. 37. Also see Werner Rothengatter, "Obstacles to the Use of Economic Instruments in Transport Policy," in *Internalising the Social Costs of Transport*, OECD, 1994.
[41] Kenneth Button, *Internalising the Social Costs of Transport*, OECD, 1994, p.12.
[42] *Final Report on the Federal Highway Cost Allocation Study*, USDOT, FHWA, 1982, p. E-9.
[43] Werner Rothengatter, "Do External Benefits Compensate for External Costs of Transport?", *Transportation Research*, Vol. 28A, 1991, p.321-328; Dr. Heini Sommer, Felix Walter, Rene Neuenschwander, *External Benefits of Transport?*, ECOPLAN (Bern), March 1993.

A recent Office of Technology Assessment report also explores the possibility that driving offers external benefits to society, which might include economies of scale in retail, out-of-home social activities, and spontaneous trip making.[44] Whether any of the benefits described (such as improved access to evening education and social activities) are unique to automobile travel and cannot be provided by other transportation systems is not discussed. That report demonstrates no significant external benefits that could approach the magnitude of external costs, nor does this report indicate external *marginal* benefits to justify increased automobile use or underpricing.

Most claimed external benefits of driving are actually external benefits of *access*. Focusing on just one mode would fail to obtain the full potential benefits of transportation improvements. Even proponents of increased infrastructure investment such as Dr. David Aschauer point out that optimum future infrastructure investments are likely to be less emphasis on roads and motor vehicle traffic than in the past, and that transit investments provide twice the rate of return as highway investments.[45]

External benefits, when they do exist, are usually captured in market competition. If driving provides external benefits, businesses or communities will compete for it, offering incentives until benefits are internalized. For example, communities often subsidize roads and parking facilities to attract development. This may provide a benefit to the first communities to use this approach, but other communities will then be forced to provide comparable subsidies until most benefits are captured by developers or new residents.

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[44] *Saving Energy in U.S. Transportation*, Office of Technology Assessment, 1994, p. 97.
[45] Dr. David Aschauer, *Public Investment and Private Sector Growth*, Economic Policy Institute (Washington DC), 1990; Dr. David Aschauer, *Transportation Spending and Economic Growth*, American Public Transit Association (Washington DC), 1991.

Since user fees do not cover the full cost of increasing road capacity to eliminate growing traffic congestion, automobile use appears to experience diseconomies of scale. In other words each driver benefits if others drive less, making road space and parking available. This implies that the overall benefits of driving would probably increase if user prices were raised to internalize a greater portion of costs, to discourage driving. In this way, low value travel would decrease and reduced congestion would make travel more efficient.

Just as patriotism is called the "last refuge of a scoundrel" because it can be used to justify careless and selfish motives, so the potential of external transportation benefits is often invoked to avoid scrutiny which might illuminate poor analysis, selfish interests and strategies that increase social costs. Although automobile use provides significant benefits, that is no reason to underprice or otherwise encourage increased driving. Virtually all objective studies conclude that motor vehicle users should bear the full costs of driving.

6.4 Land Use Impacts of Underpricing

Transportation has direct and indirect impacts on land values and use.[46] These result in benefits, which are largely capitalized into the value of land,[47] and external costs, as described in Chapter 3.14.

The tendency of land values to reflect access costs and capture transportation improvement benefits is the basis for location theory, a seminal concept in economics.[48] If highways improve access between urban and rural areas, rural property values increase as urban home buyers compete with other rural land uses. This provides profits to current (often speculating) land owners, increases the supply of land available for urban type

[46] Terry Moore and Paul Thorsnes, *The Transportation/Land Use Connection*, American Planning Association, Report #448/449 (Chicago), 1994; "The Transportation Land-Use Link," *Journal of Planning Literature*, Vol. 9, No. 2, Nov. 1994, p. 128-145.
[47] That is, they result in higher property values to current land owners and lower real estate prices to buyers for a given combination of land amenity and access.
[48] Donald McCloskey, *The Applied Theory of Price*, MacMillan, 1985.

development, and reduces urban land prices. It can also allow rural residents to compete for urban jobs, benefiting rural residents and employers, and access urban services.

An automobile-oriented transportation system requires a relatively large portion of land, leaving less for other uses. About 50% of land area in automobile-oriented cities is devoted to roads and parking, compared with about 10% in pre-automobile cities.[49] This increase in transport facility land requirements can be considered a cost of automobile use. Devoting land to roads and parking imposes of external costs, including increased competition for the remaining land,[50] environmental impacts and automobile dependency.

Transport is used by individuals to compete for desirable locations. People often face tradeoffs between travel and location costs: lower priced urban fringe land requires more driving. This has important implications on land use. In the short term transportation improvements allow people to get to the same destinations more quickly, but in the long term people tend to take more or longer trips, increasing urban sprawl. At one time this was considered good for society.[51] Exurban development allows individuals to purchase more land, privacy, and rural amenities than they can in a city. Melvin Webber states,

> *"Today* [1985] *people are moving into outlying areas because technological improvements in transportation and communications have reduced the real cost of traveling and communicating...current transportation and communication systems are generating new forms of urbanization that are highly efficient, yet spread over thousands of square miles. I suggest that this calls for celebration, not commiseration. It promises unprecedently amiable living and working arrangements in pleasant surroundings and increasingly intimate contact with friends and associates, many of whom may be located miles away. When combined with high automobility, the exurbs*

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[49] World Bank, cited in Harry Dimitriou, *Urban Transport Planning*, Routledge, 1992, p. 136. Note this is larger than the estimated 30% of land devoted just to roads in automobile dependent cities.

[50] If the supply of exurban land is unlimited, land used for urban roads is more than offset by increased access to this cheap land, resulting in reduced overall land prices. But as competition for exurban land increases, consumption of land for roads and parking reduces total available land, raising prices.

[51] James Kunstler, *The Geography of Nowhere*, Simon & Schuster, 1993, p. 39; Peter Muller, "Transportation and Urban Form," in *Geography of Urban Transportation*, Guilford Press (NY), 1986.

> *promise spacious residential sites, temporal proximity to numerous employment sites, and relatively easy access to recreational resources and culturally rich activities."*[52]

Webber is only half correct. While increased driving allows individuals access to land that is less impacted by urban problems, it expands the range and scale of those impacts, so net benefits are reduced. Webber ignores the external costs of exurban development, increased internal and external costs of driving, and the problems faced by non-drivers, which call into question his claim of "efficiency."

Competition for exurban locations creates a self-perpetuating cycle of increased costs, since increased motor vehicle traffic degrades the urban environment, thereby increasing the desire by individuals for exurban residences. This creates a "social dilemma" in which individuals' short term interests are in conflict with society's long-term interest.[53] The stakes continuously rise, so an increasing portion of user benefits are dissipated on transport costs and capitalized in land values. Researchers find that the time people spend on transport varies little, regardless of speed or travel mode.[54] As a result, it is possible that little or no overall benefit is derived from a substantial increase in driving. The tendency of increased travel speeds to result in dispersed destinations, no reduction in travel time, and increased overall travel costs, is described as *space pollution* and *time pollution*.[55] Whitelegg writes,

> *"Those who use technology to travel at greater speeds still have to make the same amount of contacts--still work, eat, sleep and play in the same proportions as always. They simply do these further apart from each other."*

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[52] Melvin Webber, "The Emerging Metropolis: Trends and Trepidations." In: *Metropolitan Growth Centers: A New Challenge for Public-Private Cooperation*, UMTA-CA-06-0196-1, Nov. 1985, p.9, quoted in Homberger, Kell and Perkins, *Fundamentals of Traffic Engineering, 13th Edition*, Institute of Transportation Studies, UCB (Berkeley), 1992, p. 2-12.
[53] Emin Tengstrom, *Use of the Automobile*, Swedish Transport Research Board (Stockholm), 1992, p. 59. Also see Garret Hardin, "Tragedy of the Commons," *Science Magazine*, Dec. 1968, pp. 1243-1247.
[54] Gordon Stokes, "Travel Time Budgets and Their Relevance for Forecasting the Future Amount of Travel, in *Proceedings of European Transport Forum*, PTRC, Sept. 1994, p. 25-36.
[55] John Whitelegg, "Time Pollution," *The Ecologist*, Vol. 23, No. 4, July/Aug. 1993, p. 131-134.

As discussed in Chapter 3.14, sprawl has significant environmental and social costs, including degradation of natural habitat, ecosystems, and aesthetic amenities, reduced community cohesion, increased per household municipal service costs and increased long term transportation costs. Sprawled land use tends to be highly automobile dependent, leading to more per capita driving and increased external costs. Automobile dependency also increases dispersion of destinations within urban areas, leading to longer average trip distances and a larger gap between drivers and non-drivers. Many urban planners now argue that land uses have become unnecessarily separated and recommend more mixing of compatible land uses.[56] These land use impacts are exacerbated by underpriced driving, and to a lesser degree by underpricing other long distance travel modes such as van and car pooling, commuter rail, and telecommuting.

Growth Control or Traffic Control?
Although increased driving is justified by Webber and others to allow residents to avoid urban problems, many such problems result from automobile use. The concerns associated with increased urban density and growth are typically dominated by traffic and parking congestion, traffic noise and air pollution, reduced open space, and higher taxes required to provide new infrastructure. Rather than focusing on limiting population growth, communities may benefit more from reducing automobile use.

Exactly how benefits are distributed between land sellers and land buyers depends on specific market circumstances. Since the benefits of increased travel and reduced development density are largely internal, while many costs are external, underpriced transportation increases conflicts between individual and societal interests. Market efficiency depends on prices reflecting marginal costs, so underpricing increases the likelihood that transportation improvements and increased travel may result in no net benefit when both internal and external costs are balanced against benefits.

[56] For example see *The Land Use-Air Quality Linkage*, California Air Resources Board, 1994, p. 9.

Douglass Lee argues that transport and land use patterns are significantly distorted by underpricing (including externalized environmental and social costs), overinvestment in roads, and distortions in land markets such as overly restrictive zoning, all of which tend to reinforce each other, increasing automobile use and sprawl.[57] He concludes that an efficient transportation/land use system would increase economic efficiency, reduce total transport expenses, reduce subsidies and tax burdens on non-users, improve urban environmental quality, reduce urban sprawl, and increase the use of efficient travel modes.

6.5 Transportation Decision Making and Underpricing

From society's perspective, all costs and benefits must be considered in each decision, but the perspective of individual decision makers is often more limited. People tend to have different, often conflicting perspectives of transport costs and benefits, depending on their role (Table 6-3). Even definitions of *cost*, *benefit*, *equity*, and *efficiency* can differ. These differing perspectives and definitions create conflicts over goals, objectives and strategies, and can result in decisions that increase overall costs and reduce overall efficiency.

Table 6-3 **Stakeholder Perspectives of Transport Benefits and Cost**

Perspective	Costs	Benefits
Society	*All costs*	*All benefits*
Driver	Time, vehicle costs, risk	Mileage
Non-Driver	Time, fares, discomfort, risk	Access
Politician	Political jurisdiction costs	Political jurisdiction benefits
Highway Planner	Roadway and drivers' costs	Vehicle mileage, road capacity
Urban Planner	Facility costs, traffic impacts	Mobility/Access
Energy Planner	Fuel consumption	Mobility/Access
Environmentalist	Environmental impacts	Mobility/Access

The definition of transportation costs and benefits varies depending on a person's perspective. These differences lead to conflicts between stakeholders.

[57] Douglass Lee, "A Market-Oriented Transportation and Land Use System: How Different Would it Be?" in *Privatization and Deregulation in Passenger Transport: Selected Proceedings of the 2nd International Conference*, Espoo, Finland, Viatek, Ltd., June 1992, pp. 219-238.

Another way to view the conflicts in our transport system is to consider average cost curves of driving from three perspectives:

1. **Users**, who decide how much to travel.
2. **Transportation agencies**, which supply road facilities.
3. **Society**, which bears environmental and social costs.

Each perceives different automobile use cost curves, as illustrated in Figure 6-2. Individuals face incentives to maximize and increase their total driving, *"to get their money's worth"* from large fixed investments in automobiles. The transport agency's U-shaped average cost curve implies economies of scale when roadway development is a goal giving politicians and transport professionals an incentive for underpricing.[58] Once congestion develops there is little or no economic justification for underpricing, but there are frequently institutional benefits since public agency funding depends on dedicated fuel taxes. The upward sloping cost curves associated with congestion, and with social and environmental costs, means that society increasingly benefits from reduced driving. As a result of these different price signals, the perspectives of individual drivers and automobile oriented planners conflict with progressive transportation planners and society in general.

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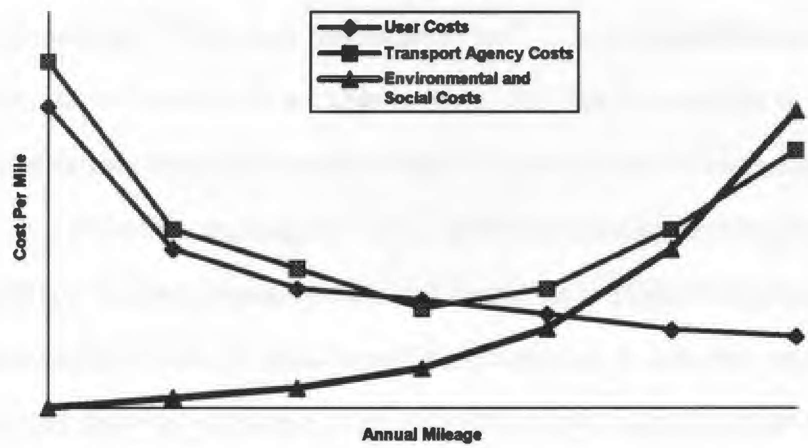
[58] Decision makers perceive benefits that exceed investment costs and conclude, "This road improvement program is good for the community.", or "A small tax expenditure offers many benefits." See Stephen Goddard's *Getting There* for discussion of the arguments used by road advocates to gain support.

Figure 6-2 **Motor Vehicle Use Conflicting Cost Curves**



Since most motor vehicle costs are fixed, average costs decrease with increase mileage. Automobile owners face incentives to maximize their driving. Facility development has a downward sloping cost curve (economies of scale) when traffic is low, since increased driving allows costs to be divided among more miles of use. Once the system becomes congested average costs increase. Most environmental, and social costs of driving are minimal when use is low, but slope upward, especially once congestion develops.

The emphasis on increasing automobile capacity, rather than broader community development and environmental goals, has become deeply ingrained in transportation planning and financing. The existence of dedicated roadway agencies and funding skews planning decisions toward roadway development. As described by Harry Dimitriou,

> "*...the conventional bias in traditional* [planning] *methodologies with their concern for transport systems efficiency above all else, exists because those most intimately involved in such approaches are well equipped with tools and techniques to design and plan 'operational efficient' networks, whereas the equivalent expertise in the planning and management of more 'developmentally effective' transport systems is much less advanced.*"[59]

By articulating the differing perspectives held by various stakeholders in the transportation planning process, participants can begin to understand and resolve the conflicts that exist.

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[59] Harry Dimitriou, *Urban Transport Planning*, Routledge (NY), 1992, p. 220.

6.6 Summary: Implications of Underpricing on Households and Individuals

You may be wondering, *"What does this mean to me?"* Underpriced driving provides various benefits. More households are able to own a car, live in suburban and exurban areas, and travel farther than if prices were higher. It gives drivers a competitive advantage in obtaining jobs, education, housing, services, safety and status over non-drivers. To what degree these effects increase overall wealth and happiness is difficult to determine.[60] At least some, and perhaps most, of these benefits are captured. In addition, underpricing imposes costs that show up elsewhere in household budgets, such as higher consumer prices to pay for "free" parking, higher taxes to pay for roads and related services, and increased health costs.

The effects of transport underpricing on commercial activities and employment are uncertain. It benefits some industries and firms but burdens others. At one time, underpricing may have provided significant external benefits by reducing average roadway and industrial development costs. These are historical benefits. There is no evidence that current driving provides external marginal benefits, which is to say that you benefit overall if your neighbors drive more. Documented negative effects of underpriced driving include:

- Increased overall transportation costs. Low marginal prices for driving encourage individuals to spend a greater portion of their budget on driving and incur greater external costs. U.S. residents spend a greater portion of household expenditures on transportation than people in other countries, and the U.S. devotes a greater portion of GDP on transport than most other nations.
- Increased automobile dependency and reduced transportation choices, since fewer people (especially middle- and upper-class people who have resources) walk, bicycle,

[60] For an inquire into whether increased wealth and driving provides increased happiness see Richard Douthwaite, *The Growth Illusion*, Council Oak Books (Tulsa), 1993. This book also explores many of the overall negative impacts of increased automobile dependency and use.

or ride public transit and trains, so services and facilities have received significantly less investment over the last century than would otherwise occur.

- More pollution (air, noise, water) and resource consumption, especially petroleum, and increased motor vehicle accidents.
- Increased resources devoted to roads, parking facilities and automobile oriented services. This means that more land is removed from other productive uses, higher taxes, or reductions in other government services, and higher costs for many services to pay for "free" parking.
- Automobile oriented land use, economic and social patterns. Increased centralization and scale of services and activities, and less emphasis on neighborhood activities, services and relationships. The use and usefulness of streets for non-driving purposes, including walking, playing and other socializing has declined. There is evidence that fewer pedestrians on streets reduces the safety of those who do walk.

How these affect you, or any specific individual or household depends on many factors including driving ability and automobile ownership, income, residence and job location, and future goals. The benefits of underpriced driving are highly skewed toward those who drive the most, which includes people who are relatively wealthy, exurban and rural residents, and long distance commuters. Children and teenagers, the elderly, the very poor and the handicapped tend to use automobiles relatively little, receive the least benefits of underpricing and suffer the most disbenefits. The effects of underpricing on middle- and lower-middle class families appears mixed. Although they enjoy benefits from driving, they are forced to spend more resources on transport than would be necessary with a less automobile dependent transportation system, which strains many household budgets.

The costs of underpriced driving depend on how much you value environmental protection, much you enjoy walking, bicycling and interacting with neighbors, and what importance you place on providing benefits for economically, physically and socially disadvantage people, and future generations.

The effects of underpriced transport on individuals and families depends significantly on whether the analysis is individual or social, short or long term. Many benefits of underpricing give individuals competitive advantages, but provide little or no overall benefit to society. From a social rather than an individual perspective, all costs, including external costs, must be considered, which further reduces the net benefits expected from underpricing. Many of the benefits of underpricing (and disbenefits of increased prices) decrease over time as individuals and communities respond by changing expectations (such as the size and number of automobiles that are expected to maintain a household at a certain status level), changes in land use, and investments in alternative travel modes. A short term, individualistic perspective will estimate much greater benefits and fewer costs of underpricing than will a long term, social perspective.

The effects of increased transport prices depends how new prices are structured, how quickly and predictably changes occur, whether alternative travel (walking, bicycling, bus and train) provisions are improved, and how revenues are distributed. Many of the costs ascribed to transportation price increases, such as unemployment in automobile oriented sectors, are temporary and avoidable transition costs.

7.0 Evaluating Transportation Equity

The benefits and costs of transportation are not allocated equally. Is that fair? This chapter explores the concept of transportation equity and suggests better ways to incorporate fairness into transportation decisions.

7.1 Defining Transportation Equity

Although equity (fairness) is often cited as a concern in transportation decisions, this subject has received little research among transportation professionals.[1] What is meant by *transportation equity* is often unclear. There are three common definitions:

1. *Horizontal Equity.*

   This is concerned with the fairness of cost and benefit allocation between groups who have comparable wealth and ability. Horizontal equity is cited when communities battle for transport funding, and when charges are distributed among transport system users.

2. *Vertical Equity, By Income*

   This focuses on the allocation of costs between income classes. According to this definition transport is most equitable if it provides the greatest benefit at the least cost to the poor, therefore compensating for overall social inequity. This definition is often used to support transport subsidies and oppose price increases.

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[1] Overviews of transport equity include Hank Dittmar, "Isn't It Time We Talked About Equity" *Progress*, Vol. IV, No. 5, Surface Transportation Policy Project, June 1994; Schaeffer and Sclar, *Access for All*, Columbia University Press (New York), 1980; David Hodge, "Social Impacts of Urban Transportation Decisions: Equity Impacts," in *The Geography of Urban Transportation*, Susan Hanson (Ed.) Guilford Press (New York), 1986; Rosenbloom and Altshuler in "Equity Issues in Urban Transportation", *Policy Studies Journal*, Autumn 1977, p. 29-39. The *Highway Cost & Pricing Study*, by Cambridge Systematics for the Wisconsin Dept. of Transportation Translinks 21 project includes comprehensive equity analysis.

3. *Vertical Equity, By Need/Ability*

This is a measure of whether an individual is relatively transportation disadvantaged compared with others in their community. It assumes that everyone should enjoy at least a basic level of access, even if people with special needs require more resources per mile, per trip or per person. Applying this concept is difficult because there are currently no standards for transport need, nor a consistent way to measure access.

Quantifying Transportation by Access

Access depends on the time, expense and effort required to reach destinations and services. It varies with individual and community circumstances, making it difficult to quantify. For example, who has better access, a low income driver in an automobile dependent city, or a low income non-driver in a multi-modal community? Does a non-driver who can afford taxi fares have mobility problems? Are children in auto dependent communities disadvantaged because they must be chauffeured to any destination?

7.2 Current Transportation Equity Analysis

Most current analyses of transportation equity focus on only one type of equity and consider only market effects. Examples are described below.

Horizontal Equity

Horizontal equity is often an issue in the allocation of transport funds to geographic jurisdictions because transportation projects provide short term economic stimulation (jobs and contracts) and long term economic development. Political representatives often fight for a fair share of this money and various formulas and decision making frameworks have been developed to distribute these resources fairly. Some studies examine the ratio between the state or federal transportation tax contributions from a jurisdiction and the funding it receives back, on the assumption that a low ratio would be unfair.

The equitable distribution of costs and benefits between modes and vehicle classes has received a moderate amount of research among transportation economists. A number of cost allocation studies have examined whether different vehicle classes (automobiles, medium trucks and heavy trucks) pay a fair share of the costs they impose on the roadway in taxes.[2] One study compares overall automobile financial costs and revenues.[3] A few studies have also compared the costs of road and rail transport.[4]

An increasing concern is the equity of disbenefits to a community caused by a transport project that provides few local benefits.[5] Urban neighborhoods are negatively impacted by freeways or other road improvements that primarily benefit suburban commuters. For example, despite vigorous opposition, freeway construction in the late 1950's leveled 750 African American homes and businesses in Nashville, Tennessee, virtually destroyed that community.[6] In addition to being unfair in terms of horizontal equity, this frequently imposes vertical inequity since the people who are impacted tend to be less affluent than the drivers who use the facilities. Such unfair treatment of local communities lead to "freeway revolts" which often pit poorer urban residents against suburban development interests. This resistance has stopped many planned urban freeway projects.

Income Equity

Underpricing driving is often justified for the sake of income equity. A few studies have examined the distribution of transport financial costs and benefits by income class, and the impacts of price changes. One study examined the effects of sudden oil price increases by

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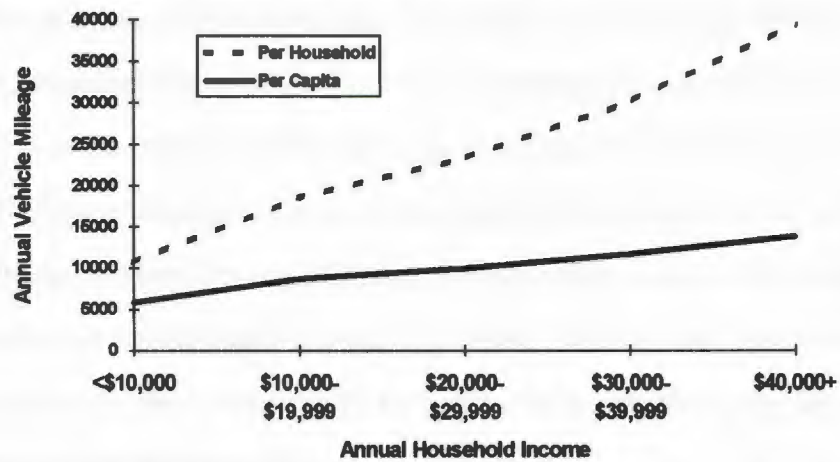
[2] Kenneth Small, et al, *Road Work*, Brookings Institute (Washington DC), 1989.
[3] Cora Roelofs and Charles Komanoff, *Subsidies for Traffic: How Taxpayer Dollars Underwrite Driving in New York State*, Tri-State Transportation Campaign (NY), 1994.
[4] Transport Concepts, *External Costs of Truck and Train*, Brotherhood of Maintenance of Way Employees (Ottawa), Nov. 1994.
[5] Helen Leavitt, *Superhighway-Superhoax*, Ballantine, 1970; Ben Kelley, *The Pavers and the Paved*, Brown, 1971; Stephen Goddard, *Getting There*, Basic Books (New York), 1994, especially chapter 13.
[6] David Hodge, "Social Impacts of Urban Transportation Decisions: Equity Impacts," in *The Geography of Urban Transportation*, Susan Hansen (Ed.) Guilford Press (New York), 1986, p. 302.

income class and concluded that, "*The greatest beneficiaries of lower energy prices would be the poor.*"[7] Merle Mitchell argues that fuel taxes are regressive since the lowest income households spend a larger portion of income on motor vehicle fuel than the highest income class.[8] Mark French concludes that a $0.15 per gallon fuel tax increase would be regressive with respect to income,[9] although his analysis significantly overstates this factor by assuming incorrectly that driving and fuel consumption rates are the same for all income classes. The poor, especially the very poor, own fewer automobiles, drive less and rely more on alternatives to driving (Figure 7-1) than the rich.[10]

Figure 7-1 **Annual Vehicle Travel By Income**[11]



Higher income households and individuals use motor vehicles more than those with lower incomes, and thus enjoy a greater share of benefits and user subsidies. This implies that reducing subsidies to driving may be progressive if savings benefit poor households.

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7 Steven Rock, "Distributional Changes in Consumer Transportation Expenditures: 1972-1985," *Transportation Research Record 1197*.
8 See for example Merle Mitchell, "Links Between Transport Policy and Social Policy," in *Transport Policies for the New Millennium*, Ogden et al. editors, Monash University (Clayton), 1994.
9 Mark French, "Efficiency and Equity of a Gasoline Tax Increase," *Energy Systems and Policy*, Vol. 13, 1989, pp. 141-155. It incorrectly assumes that average fuel consumption is the same for all income levels.
10 Golob, "Casual Influence of Income and Car Ownership," *Transport Economics*, May 1989, p. 149.
11 Hu and Young, *1990 NPTS Databook, Vol.1*, FHWA (Washington DC), Nov. 1993, Table 3.14.

The actual burden imposed on poor households by increased automobile taxes is less certain than these studies imply. James Poterba has demonstrated that the poorest households actually spend a smaller portion of their annual *expenditures* (which he considers a more appropriate reference than *income*) on gasoline than middle class families, and concludes that, *"The gasoline tax thus appears far less regressive than conventional analyses suggest."*[12] His work indicates that fuel taxes have little or no regressivity relative to *lifetime* expenditures.[13]

Werner Rothengatter argues that wealthier European drivers misrepresents equity concerns to justify low vehicle use taxes that are actually regressive due to higher automobile use by wealthier households.[14] Similarly, David Banister indicates that a 26% increase in British petroleum prices would be a progressive tax with respect to income since many poor households do not own a car.[15] Shifting fixed vehicle ownership taxes to variable vehicle use taxes would be even more progressive since poor car-owning households tend to drive less annually per automobile than wealthier households. He concludes that the overall equity impacts of increased vehicle taxes depends in part on whether automobile use is considered a necessity or a luxury, since poor households that do own cars *are* disadvantaged by such tax changes.[16]

The equity impacts of congestion pricing and other road fees has been studied by several researchers. These typically conclude that equity impacts depend on how revenues are distributed.[17] Genevieve Giuliano summarizes current research and the fairness of current

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[12] James Poterba, "Is the Gasoline Tax Regressive?", *Tax Policy and the Economy*, MIT Press, 1991.
[13] James Poterba, "Reexaminations of Tax Incidence: Lifetime Incidence and the Distributional Burden of Excise Taxes," *The American Economic Review*, Vol. 79, No. 2, May 1989, p. pp. 325-330.
[14] Werner Rothengatter, "Obstacles to the Use of Economic Instruments in Transport Policy," in *Internalising the Social Costs of Transport*, OECD (Paris), 1994.
[15] David Banister, "Equity and Acceptability Questions in Internalising the Social Costs of Transport," in *Internalising the Social Costs of Transport*, OECD (Paris), 1994.
[16] Banister's analysis of the equity impacts of urban road pricing appear to assume that automobile use is a necessity, even by city dwellers, despite evidence he presents to the contrary.
[17] Ken Small, "Using the Revenues from Congestion Pricing," *Transportation*, 19/4, pp. 359-381.

road funding mechanisms, which she concludes are overall regressive (Table 7-1).[18] She emphasizes the problems facing women commuters in shifting from SOV travel due to family responsibilities and inflexible employment conditions, implying an inequitable burden, and that at least some low income drivers would be worse off overall from congestion fees. She emphasizes the need to analyze impacts by gender, employment type, location, commute distance, and other criteria in addition to income. John Kain identifies significant potential benefits to poor commuters (and non-drivers) from congestion pricing by incorporating transit and ride sharing service improvements, including travel time savings and increased bus frequency, plus revenue rebates.[19]

Table 7-1 **Incidence of Taxes Used to Support Highway Services**[20]

Tax	Incidence
Federal, state fuel gasoline tax	Regressive
State use fees	Regressive
State sales tax	Regressive
Local sales tax	Regressive
Federal, state income tax	Progressive
Property tax	Regressive

Most current taxes used for roadway funding are regressive.

A recent study indicates that *Pay-As-You-Drive* insurance increases income equity by eliminating the high premiums often required for residents of low income communities, reducing costs for low annual mileage drivers, and providing overall insurance system savings.[21] Low income households would pay 30 to 80% lower premiums than under the current system, in part because low income households drive less than wealthier households. This analysis understates total potential benefits to the poor by considering

[18] Genevieve Giuliano, "Equity and Fairness Considerations of Congestion Pricing," in *Curbing Gridlock*, TRB, National Academy Press (Washington DC), 1994, p. 250-279.
[19] John Kain, "Impacts of Congestion Pricing on Transit and Carpool Demand and Supply," in *Curbing Gridlock*, TRB, National Academy Press (Washington DC), 1994, p. 502-553.
[20] Genevieve Giuliano, in *Curbing Gridlock*, National Academy Press, (Washington DC), 1994, p. 260.
[21] Jeff Allen, Roland Hwang, and Jane Kelly, *An Equity Analysis of "Pay-As-You-Drive" Automobile Insurance in California*, Union of Concerned Scientists (Washington DC), Nov. 1994.

only market costs. Reduced pollution, traffic congestion and automobile dependency would also benefit lower income households.

Michael Cameron concludes that a $0.05 per mile road user charge in Southern California would not necessarily be regressive, since all income quintiles benefit from reduced congestion and air pollution including the poorest residents.[22] Cameron suggests that this estimate probably understates benefits to the poor, since low income people tend to be exposed to higher than average pollution,[23] a factor not incorporated into his model. Although air pollution reduction benefits would be lower in other regions, Cameron considers air pollution a proxy for other environmental impacts not priced in his study, which would provide additional benefits in all regions.

Robert Johnston, et al. consider the income equity of congestion management strategies, including HOV facilities, metering, pricing, and rationing, and conclude that pricing can be equitable if revenues are appropriately spent.[24] Similarly, Ken Small states that, *"...when central cities are the recipients of the toll revenue, the toll causes a monetary transfer from rich to poor plus a uniform time saving enjoyed by all."*[25]

After examining impacts on the poor of internalizing transport costs, Per Kågeson concludes, *"...the reform (without any refund of the revenues) will do little to change the existing differences between income groups, and the strain on low income groups can be offset by refunding a portion of revenues, in equal amounts, to all citizens."*[26] Douglass

[22] *Efficiency and Fairness on the Road*, Environmental Defense Fund (Oakland), 1994.
[23] David Hodge in *The Geography of Urban Transportation*, Susan Hansen (Ed.) Guilford Press (New York), 1986, p. 303. This issue has received increasing attention as an issue of environmental justice.
[24] Robert Johnston, Jay Lund and Paul Craig, "Capacity-Allocation Methods for Reducing Urban Traffic Congestion," *Journal of Transportation Engineering*, Vol. 121, No. 1, pp. 27-39, January 1995.
[25] "The Incidence of Congestion Tolls on Urban Highways", Ken Small, *Journal of Urban Economics*, December 1983, p. 90-111.
[26] Per Kågeson, *Getting the Prices Right*, European Fed. for Transport & Env., 1993, p.185.

Lee concludes that congestion charges are unlikely to be overall regressive because peak period drivers tend to be wealthier than average. He states,

> *"...peak tolls (in the peak direction during peak hours) would be a progressive source of revenue. All existing user and non-user funding sources (such as property and sales tax) are less progressive or are regressive."*[27]

Regulation is sometimes seen as more equitable than pricing to manage markets and reduce impacts, because with pricing, *"motoring will become the prerogative of the wealthy."*[28] This conclusion is debatable since regulations increase costs (for example, increasing the price of automobiles), and penalties for failing to comply are often fines, all of which are a greater burden to low income drivers. Elizabeth Deakin finds that nearly half of all vehicles owned by poor families (annual income less than $25,000) in the San Francisco Bay area are older, high polluting models, but such households produce only 12% of mileage and 15% of trips made in these older vehicles.[29] The majority of older vehicles are owned by wealthier families, which account for 3/4 of their mileage.

Congestion is a progressive cost with respect to income because wealthier people have higher opportunity costs for their time.[30] This is tempered by the fact that wealthy drivers can afford more comfortable cars, mobile communications, a greater choice of housing locations, more flexible schedules, and in some cases alternative modes.

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[27] *Highway Pricing as a Tool for Congestion Management*, Douglass Lee, Principal Investigator, Transportation Systems Center (Cambridge), October 1989, p. 13.
[28] David Banister and Kenneth Button, "Environmental Policy and Transport: An Overview," in *Transport, the Environment and Sustainable Development*, E&FN SPON (NY), 1993, p.7.
[29] Elizabeth Deakin, "Policy Response in the USA," *Transport, the Environment and Sustainable Development*, E&FN SPON (NY), 1993, p. 95.
[30] Herbert Mohring and David Anderson, *Congestion Pricing for the Twin Cities Metropolitan Area*, Department of Economics, University of Minnesota, January 1994.

Need/Ability Based Equity

Several factors can make an individual transportation disadvantaged, including age, physical disability and poverty.[31] Approximately 26% of the U.S. population is under 18, and about 12% is over 65 years of age.[32] Since young children couldn't travel independently even if a vehicle was available, it is the approximately 15% in the 7 to 17 range that can be considered most disadvantaged.[33] About 7% of the U.S. population is estimated to be mobility impaired due to mental or physical disability.[34] Over 13% live in poverty (defined as a family of four earning less than $13,359 annually in 1990).

The 1990 National Personal Transportation Survey indicates that 9.2% of households with 6.4% of the population do not own an automobile, but since this survey is based on telephone interviews it is believed to underrepresent poor households.[35] The 1989 American Housing Survey and the 1990 Census indicate that 15.9% and 11.5% of households own no automobile respectively, so the portion of the population living in a household without a car is probably about 10%. The number of households without vehicles may be a poor indicator of the total number of people who are transportation disadvantaged. Simply because an individual lives in a household that has at least one automobile is no proof they are not transportation disadvantaged due to automobile dependency. Increasing travel demands and reduced travel choice mean that a personal automobile is required for full participation in society. Automobile transportation is increasingly required for jobs, schooling, recreation and participation in civic activities.

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31 "Mobility or, Rather the Lack of It" in *Transport Sociology*, by Hillman, Koutsopoulos, Schmidt, Henerrson, and Whalley.

32 *The World Almanac, 1993*, Pharos Books (New York), 1993.

33 Although 16 and 17 year olds can obtain drivers licenses, and some people over 65 continue to drive, young driver's freedom is often limited by access to vehicles and liability insurance costs, and many people younger than 65 must curtail their driving due to age related constraints, so the under 18 and over 65 age ranges seem reasonable to represent portions of the population that are transport disadvantaged by age.

34 John Meyer and José Gómez-Ibáñez, *Autos Transit and Cities*, Harvard U. Press (Cambridge), 1981.

35 Richard Crepeau, *Zero Vehicle Households: Issues of Transport and Housing*, 1995 TRB General Meeting (Washington DC).

There is considerable overlap between the transportation disadvantaged groups described above. In their 1981 book *Autos Transit and Cities,* John Meyer and José Gómez-Ibáñez estimate that 23% of the U.S. population is transportation disadvantaged due to some combination of poverty, disability or age over 65. Including young people aged 7 to 17 would indicate that 1/3 or more of the population is transportation disadvantaged. According to some studies, women tend to be represented in transportation disadvantaged categories more than men.[36]

Need based transportation equity concerns tend to focus on two issues. One is access for physically disabled people to public facilities, which has resulted in the passage of various handicapped access requirements including the Americans with Disabilities Act. The second area of attention is support for transit and special mobility services to provide a basic level of mobility for all residents. Although there is no doubt that many transport disadvantaged people rely on public transit, there is little research on the degree to which they depend on transit, and even less information on how much these groups use other modes, such as bicycling and walking.

Few current analyses consider both income and need/ability equity,[37] and none effectively incorporate non-market effects such as the distribution of pollution, accident costs or comfort by income or ability. Most equity analysis focus on the short term, failing to consider long term effects on land use and automobile dependency. Failing to consider these impacts ignores important equity considerations and tends to skew results toward justification of underpricing and continued overemphasis on automobile transport.

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[36]Julia Walton, "Gender and Urban Form," *The Urban Ecologist*, Fall 1993; Karen Overton, "Auto-Dependence: A Driving Force for Gender Inequality," *The Urban Ecologist*, 1995, No. 1, p. 16.
[37] An exception is *Access to Opportunity: Cooperative Planning to Improve Mobility for Residents of Inner-City Communities*, East-West Gateway Coordination Council (St. Louis, MO), 1995.

7.3 Automobile Dependency as an Equity Issue

Due to its importance in economic and personal development mobility is frequently considered a necessity and even a right.[38] Some trips are considered more important to society than others, and can be defined as "basic mobility." This basic level of mobility includes access to services and employment, and to a lesser degree social and recreational activities. Whether increased prices for driving is inequitable to low income drivers depends in part on whether driving is a necessity or a luxury. If poor people *must* drive, any increase in user prices is an inescapable and unfair burden. If usable transport alternatives exist then increased prices can be considered acceptable. However, if driving *is* a necessity, then non-drivers are disadvantaged even if driving is cheap, and their relative disadvantage is exacerbated by anything which decreases their transport options. This issue is explored in this section.

The degree to which transport, land use and social patterns emphasize driving relative to other modes is called *Automobile Dependency*.[39] Automobile dependency can create a self-perpetuating cycle. As discussed in chapters 3.9 (Equity), 3.13 (Barrier Effect), and 3.14 (Land Use Impacts), automobile use increases barriers to pedestrian and bicycle travel, reduces the viability of transport alternatives, and increases the amount of travel between destinations, all of which further increases driving.

The equity impacts of automobile dependency can be defined in formal economic language. Consider all trips you would like to take during a time period ranked from highest to lowest user cost (including financial costs, time, accident risk, and comfort). Economists call this a *supply curve*. This transport supply curve varies from one individual and community to another. For many trips, non-drivers have significantly higher costs than drivers. This difference increases as communities become automobile dependent, as travel

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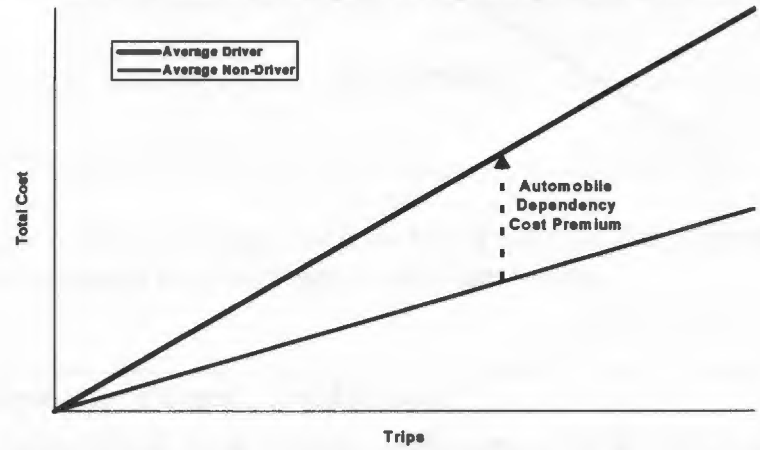
[38] John Hamburg, Larry Blair and David Albright, *Mobility as a Right*, TRB Annual Meeting, Jan. 1995.
[39] Peter Newman and Jeff Kenworthy, *Cities and Automobile Dependency*, Gower (Aldershot), 1989.

needs increase, land use becomes more dispersed and other travel modes decline. This average cost premium for non-drivers varies from one community to another depending on the degree of automobile dependency. This is illustrated in Figure 7-2.

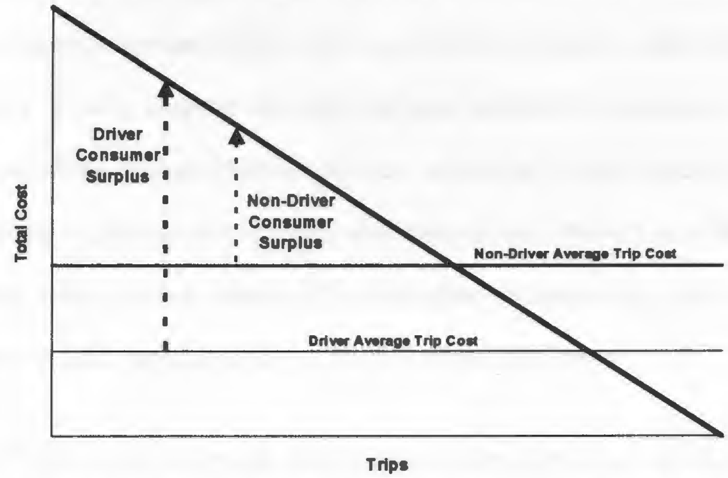
Figure 7-2 **Transportation Supply Curve for Drivers and Non-Drivers**



Each individual faces a different transportation supply curve (the costs of trips ranked from lowest to highest). In most communities non-drivers have significantly higher total costs, which reflects the degree of automobile dependency.

Economists measure benefits of consumer expenditures net their costs, called *consumer surplus*. If the average cost of travel is higher for non-drivers than drivers, non-drivers enjoy less consumer surplus. This is illustrated in Figure 7-3. This difference in consumer surplus between drivers and non-drivers is one way to measure transportation inequity. Automobile dependency increases this difference in consumer surplus between drivers and non-drivers. It is also unfair to low income drivers who must spend a greater portion of their income on transport than they would otherwise, leaving fewer resources for other expenditures and less consumer surplus.

Figure 7-3 **Consumer Surplus of Drivers and Non-Drivers**



Costs per trip are higher on average for non-drivers compared with drivers. Non-drivers take fewer trips and enjoy less consumer surplus than drivers.

Automobile Dependency Equity Cost Example[40]

The Chimawa Indian Health Clinic provides health care to Native Americans in Western Oregon. It has over 18,000 regular clients. When opened in 1970 the clinic had no public transit service. Patients who relied on transit, including those who were sick, pregnant, disabled, elderly and children, had to walk a mile on a muddy trail from the nearest bus stop. After years of political pressure, protests and legal challenges the local transit agency extended the bus route to the clinic, but this service is in jeopardy due to low ridership.

This illustrates the equity costs of automobile dependency. If the community was less automobile dependent, transit access would have been a requirement when originally siting the facility. A larger portion of non-driver employees and patients would create demand for better transit service, pedestrian and bicycle facilities. Automobile dependency forces households to own automobiles whether or not they can afford the costs to access critical services such as health care. Since these costs are most significant for people who are already disadvantaged (the poor, handicapped, and elderly), it is inequitable.

[40] Jacky Grimshaw, *Impacts of Siting Non-Transportation Public Facilities*, Center for Neighborhood Technology (Chicago), November 1994.

7.4 Comprehensive Transportation Equity Analysis

The total cost perspective presented in this report allows a more comprehensive analysis of transport equity. Equity analysis depends on how transportation system user classes are defined. Major variables include location (urban, suburban, rural), income (low, medium, high), physical ability (disabled non-driver, able non-driver, driver), and lifecycle stage (child, adolescent, adult, parent, elderly). For the sake of simplicity, users are divided into four major classes which capture many of the variables just listed:

- *Non-drivers.* This includes people who cannot drive due to age or disability, or poverty. Non-drivers use automobiles as passengers, but except for those who can afford unlimited chauffeuring, their use is typically much less than drivers.
- *Low income drivers.* This includes people who can drive and have access to an automobile but whose travel decisions are significantly affected by financial costs. Vehicle user prices have a major effect on their travel habits.
- *Middle income drivers.* This includes drivers who normally have unrestricted access to an automobile and who are only moderately burdened by their automobile financial costs. Vehicle user prices have a moderate effect on their travel habits.
- *Upper income drivers.* This includes drivers who normally have unrestricted access to an automobile and are not burdened by their automobile financial costs. Vehicle user prices have little effect on their travel habits.

For equity analysis, transportation costs are divided into six categories:

1. *User market.* These include vehicle ownership and operating costs, out-of-pocket parking expenses, and transit fares. These are the focus of most transportation planning and equity analysis.

2. *User non-market*. These include user travel time, accident risk and comfort. These are often recognized in planning but are frequently ignored in equity analysis. For example, few analysis formally identify how the speed, safety and comfort benefits of a transportation decision are distributed by income or user class, although this is sometimes considered informally when allocating transport resources between different geographic locations, or between automobile and transit investments.

3. *External market*. These include roadway facility costs, parking subsidies, and transit subsidies that originate as general taxes or increased consumer prices. Equity is sometimes a factor in the allocation of these costs and benefits (for example, in the allocation of road tax burdens between different motor vehicle classes) but there is often disagreement as to how equity should be measured.

4. *External environmental*. This includes noise, air and water pollution, the barrier effect, aesthetic degradation, and habitat loss. These are sometimes considered during transportation planning but are usually ignored in equity analysis. For example, there is little data on the impacts of air pollution or the barrier effect by income class. Some analyses assume environmental benefits are valued most highly by wealthy residents, while others point out that pollution costs tend to be borne most by lower income residents, but little quantitative research has been done.

5. *Automobile dependency.* This includes the costs of reduced transportation choices and generated traffic that result from automobile dependent transportation system and land use patterns. These are seldom incorporated in transport planning or equity analysis, although some recent discussions of sustainable community planning consider them.

6. *Economic.* This includes changes in consumer prices, economic development, employment, and productivity, as discussed in sections 5.1 and 5.2. These costs are

frequently cited in general discussions of transportation policy, but little quantitative research has been done. Many claimed economic benefits of transport improvements are distributional, representing gain in one community that is offset by a loss elsewhere, which is a horizontally inequitable. Except for a few studies of the employment benefits of specific transportation projects, few studies have examined how such costs and benefits are distributed by income or class. Transaction costs, such as economic changes that result in unemployment among traditional industries tend to be vertically inequitable since disadvantaged people have fewer resources to fall back.

7.5 Comprehensive Equity Analysis Applications

These three user classes and six major cost categories can be used for comprehensive analyses of transportation equity impacts. Below are three examples.

Example 1. **Equity Effects of Automobile User Prices.**

As described in Chapter 4, driving is significantly underpriced. Is this equitable? Would increasing prices (higher fuel taxes or road user fees), to better reflect marginal costs and to encourage more efficient travel habits, be more or less equitable? For example, a $0.50 per gallon fuel tax increase would increase average marginal automobile costs by about 20% and total internal financial automobile costs by about 6%. It would raise about $500 billion annually in the U.S. and would decrease total driving by approximately 4%. What would be the equity impacts of such a change? Specific impacts by cost category and transportation system user class are evaluated in Table 7-2.

Table 7-3 summarizes these impacts of transportation underpricing. This analysis shows that increased prices has complex equity impacts that are ignored most analyses, including indirect benefits that are usually unrecognized. Although higher fuel taxes or a road user fees increase market costs for all drivers and force drivers (especially low income drivers) to use less desirable (to the user) travel modes for some trips, there are significant non-market benefits to all residents, including reduced congestion, reduced road and parking subsidy costs, reduced environmental impacts, and increased transport choices. These offer significant potential benefits to non-drivers and low income people.

Table 7-2 **Automobile Price Increase Equity Effects**

User Class	Cost	Expected Effect
Non-Driver	User Market	No short term change. Small long term benefits due to economies of scale in transit service.
Low Income Drivers	User Market	Higher short term costs, with mixed long term effects since drivers will sometimes shift to cheaper (but less desirable to the user) modes such as public transit, bicycling, and walking, and other times will pay the higher cost. Whether the net result is increased market costs or savings depends on the availability of substitutes. If alternatives are viable, higher driving costs will motivate a shift to these modes, resulting in overall financial saving. If few alternatives exist, low income households will spend more overall on transport.
Middle and Upper Income Drivers	User Market	Higher costs since they will usually drive despite higher prices.
Non-Drivers	User Non-Market	No short term change is likely. A moderate long term benefit is likely due to improved transit, bicycling and pedestrian service.
Low Income Drivers	User Non-Market	Significant increased costs since these users will be priced out of driving for some trips, and forced to use less desirable (to the user) modes such as transit, bicycling and walking. The size of this cost increase depends on the quality of alternative modes. This cost is offset somewhat by reduced congestion delay and accident risk.
Middle and Upper Income Drivers	User Non-Market	Moderate benefit due to reduced congestion delay and accident risk.
All Road Users	External Market	Moderate benefit, including reductions in other taxes and reduced parking subsidy costs due to less driving.
All Residents	Environmental	Moderate benefit from reduced pollution, energy consumption, and urban sprawl due to less driving.
All Residents	Automobile Dependency	Various benefits, especially for non-drivers and low-income drivers who are most likely to use the increased transport choices. These benefits increase in the long term.
All Residents	Economic	Slight short term consumer price and employment transition costs, and slight long term benefits due to productivity gains, as discussed earlier. Automobile sector job losses may be slightly regressive, but these could be offset by increased employment in transit and other sectors that substitute for driving.

The overall equity impacts of price changes depend largely on how revenues are distributed. If each income class receives revenues comparable to what they pay, the overall effect is probably slightly progressive (increases vertical equity) due to benefits to non-drivers. If some revenues are specifically targeted at disadvantaged people (the poor and non-drivers) the overall effect could be strongly progressive. Spending revenues only on new highways is probably regressive (since these are used primarily by higher income travelers), but typical expenditures on transit, bicycle and pedestrian improvements are probably progressive. Analysis of the distributional effects of increased prices and benefits by geographic area or subgroups may indicate additional horizontal inequities.

Table 7-3 **Increased Automobile Price Equity Effects Summary**

	Short Term			Long Term		
	Non-Drivers	**Low Income Drivers**	**Middle-High Income Drivers**	**Non-Drivers**	**Low Income Drivers**	**Middle-High Income Drivers**
User Market	None	Moderate Cost	Moderate Cost	Slight Benefit	Mixed	Moderate Cost
User Non-Market	Slight Benefit	Large Cost	Small Benefit	Moderate Benefit	Mixed	Small Benefit
External Market	Moderate Benefit	Moderate Benefit	Moderate Benefit	Moderate Benefit	Moderate Benefit	Moderate Benefit
Environmental	Moderate Benefit	Moderate Benefit	Moderate Benefit	Moderate Benefit	Moderate Benefit	Moderate Benefit
Auto Dependency	Large Benefit	Moderate Benefit	Slight Benefit	Large Benefit	Large Benefit	Small Benefit
Economic	Small Cost	Slight Cost	Slight Cost	Slight Benefit	Slight Benefit	Slight Benefit

Example 2 **Equity of Transit Subsidies**

Public transit service receives significant financial subsidies. Is this fair? An analysis that only considers market costs may conclude that transit subsidies are inequitable, at least in the narrow terms of horizontal equity. A comprehensive equity analysis can better identify how costs and benefits are distributed.

If all costs are considered, the difference in external costs between public transit and other travel modes is small. Figures 4.3 to 4.5 show that the external costs per passenger mile of a Diesel Bus rider are comparable to an Average Automobile during Urban Peak travel, but average bus external costs are higher under Urban Off-Peak and Rural conditions. This implies that some transit riders receive more subsidy than average drivers. However:

- Although transit riders receive a higher subsidy than drivers per mile, drivers travel much more than non-drivers per year, so transit dependent users receive a much lower annual subsidy.
- Due to unused capacity and economies of scale, a typical additional bus rider increases the transit system's efficiency, reducing the average unit subsidy. The marginal cost per rider using existing capacity is therefore low or negative.
- Transit satisfies the definition of "basic mobility" and thus should be evaluated differently from driving, which can be considered a relative luxury. It is therefore reasonable to subsidize transit use at a higher rate per mile than driving just as public health services provide subsidies for childhood immunization than for plastic surgery.
- Transit service incurs many costs such as wheelchair lifts and service to special destinations to meet community needs that should not be charged to general riders.

Taking these factors into account, the average annual subsidies received by transit riders is significantly lower than that received by drivers, indicating that drivers as a class are unfairly subsidized compared with transit riders in terms of horizontal equity. This inequity is greater if vertical equity is considered, since bus riders tend to be disadvantaged compared with average drivers. Even greater vertical inequity exists for individual transit services or routes serving low income urban riders since these are often more cost effective than those targeting wealthier suburban riders. For example, in the Los Angeles area, bus riders who are primarily lower income receive average subsidies of $1.17 per trip, while suburban rail riders who tend to be wealthier receive subsidies averaging $11 to $21 per trip.[41] BART benefits are similarly inequitable with respect to income.[42]

The user and cost categories described earlier in this section can be used to identify the benefits of transit subsidies. Table 7-4 shows how transit subsidy costs and benefits are probably distributed in a typical urban area.

Table 7-4 **Transit Subsidy Equity Effects**

User Class	Cost	Expected Effect
Non-Driver	User Market	Large benefits. Transit service would not exist in most communities without subsidies. Transit is much cheaper than alternatives such as taxies. Subsidies provide financial savings to users and allow access to jobs and a wider selection of commercial services.
Low Income Drivers	User Market	Moderate benefits. Transit is used regularly by some low income drivers, and it provides a backup when a car is unavailable.
Middle and Upper Income Drivers	User Market	Small benefit. A few affluent drivers regularly use transit such as suburban rail, and it provides a backup when a car is unavailable.
Non-Drivers	User Non-Market	Large benefit. Transit service provides many non-market benefits to non-drivers, and reduces traffic congestion and accident risk.
Low Income Drivers	User Non-Market	Moderate benefit, including reduced congestion and accident risk.
Middle and Upper Income Drivers	User Non-Market	Moderate benefit, including reduced congestion and accident risk.
All Residents	External Market	Moderate cost. Transit subsidies require additional taxes that are offset slightly by reduced automobile parking and road subsidies.
All Residents	Environmental	Moderate benefit, including reduced air pollution and urban sprawl.
All Residents	Automobile Dependency	Moderate to large benefits, including more short term mobility choices, and less car dependent transport and land use in the long term. Non-drivers benefit most.
All Residents	Economic	Mixed overall, with significant distributional effects in some areas.

[41] "LA Bus Riders Union Sues MTA," *Progress*, Vol. V, No. 1, Surface Transportation Policy Project (Washington DC), February 1995, p. 7.

[42] David Hodge, "Social Impacts of Urban Transportation Decisions: Equity Impacts," in *The Geography of Urban Transportation*, Susan Hanson Editor, Guilford Press (New York), 1986, p. 307.

Table 7-5 summarizes the impacts of transit underpricing.

Table 7-5 **Transit Subsidy Benefits Summary**

	Non-Drivers	**Low Income Drivers**	**Middle-High Income Drivers**
User Market	Large Benefit	Moderate Benefit	Small Benefit
User Non-Market	Large Benefit	Moderate Benefit	Moderate Benefit
External Market	Moderate Cost	Moderate Cost	Moderate Cost
Environmental	Moderate Benefit	Moderate Benefit	Moderate Benefit
Auto Dependency	Large Benefit	Moderate Benefit	Moderate Benefit
Economic	Mixed	Mixed	Mixed

This analysis shows a variety of transit subsidy benefits that are greatest for non-drivers, and to a smaller degree low income drivers, indicating vertical equity benefits. Analysis of the distribution of specific transit subsidy costs and benefits by route, type of service (rail vs. bus) and geographic area may indicate additional equity impacts, including horizontal equity.

The equity effects of transit service and subsidies vary considerably. As mentioned above, bus service used most by low income riders often have the highest farebox recovery, while commuter bus and rail service to higher income suburbs, airports and other special destinations are less cost effective. Funding structures that favor suburban over urban service, and therefore fail to deliver transit service where the need and system efficiency are greatest, are considered inequitable by Brian Taylor.[43] Equity analysis by type of service or route is likely to show that some transit subsidies (such as rail service to wealthy suburbs) *are* regressive but general bus service is highly progressive.[44]

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[43] Brian Taylor, "Unjust Equity: An Examination of California's Transportation Development Act," *Transportation Research Record 1297*, Transportation Research Board (Washington DC), pp. 85-92.
[44] The Los Angeles area Bus Riders Union, for example, concludes that rail transit intended for affluent riders is inequitable because it diverts funding from basic bus transit.

Example 3 **Traffic Management Equity**

Different users often have conflicting interests in roadway design. Automobile users benefit from streets designed to maximize traffic capacity and speeds, with minimal variations or distractions. Cyclists benefit from streets designed for moderate traffic speeds and volumes, with special provisions for bicycles. Pedestrians benefit from streets designed for minimal traffic speeds and volumes, and special provisions for walking and sitting.[45] Transit riders benefit from street designs that both facilitate transit movement and that enhance the pedestrian environment. Nearby residents, visitors (such as diners at a restaurant) and property owners benefit from streets designed for minimal through traffic and which accommodate other activities (sitting, playing, and community interactions).[46] Because road space and funding are usually limited, and because motor vehicle traffic has disbenefits to other users, the interests of different user groups often conflict. Roadway design decisions therefore have equity implications.

Current street design and funding practices tend to emphasize motor vehicle needs at the expense of other users. Traffic engineers refer to projects that increase motor vehicle traffic speeds and capacity as "upgrading," although this may result in reduced safety and comfort for other user classes. Specific design features that benefit drivers at the expense of other users include hierarchical street networks, wide lanes, straight alignments, smooth surfaces, large turning radii, synchronized traffic signals, and maximum surface parking. Because of limited resources, accommodating motor vehicle traffic often reduces the size and quality of sidewalks, bike paths and other facilities for non-motorized users.

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[45] Tim Pharoah, *Less Traffic, Better Towns*, Friends of the Earth (London), 1992.

[46] D. Gordon Bagby, "Effects of Traffic Flow on Residential Property Values," *Journal of the American Planning Association*, Vol. 46, No. 1, January 1980, p. 88-94. W. Hughes, Jr. and C.F. Sirmans, "Traffic Externalities and Single-Family House Prices," *Journal of Regional Science*, 32/4, 1992, pp. 487-500. Donald Appleyard, *Livable Streets*, University of California Press, 1981.

Table 7-6 **Traffic Management Equity Impacts**

User Class	Cost	Expected Effect
Non-Driver	User Market	Moderate benefit. Reduced traffic allows more walking and bicycling, reducing transit and taxi fare expenses. It can also increase the market value of residences adjacent to streets.
Low Income Drivers	User Market	Small cost. Traffic restrictions increase automobile operating costs.
Middle and Upper Income Drivers	User Market	Small cost. Traffic restrictions increase automobile operating costs.
Non-Drivers	User Non-Market	Large benefit. Traffic restrictions and pedestrian/bicycle improvements increase safety, comfort and mobility under all conditions.
Low Income Drivers	User Non-Market	Small cost. Motor vehicle traffic restrictions increase driving time but reduce accidents, and increase comfort when not driving.
Middle and Upper Income Drivers	User Non-Market	Small cost. Motor vehicle traffic restrictions increase driving time but reduce accidents, and increase comfort when not driving.
All Residents	External Market	Moderate benefit. Short term expenses required to implement traffic management projects. These are offset by savings from reduced vehicle accidents and increased property values.
All Residents	Environmental	Large benefits, including reduced traffic noise, severance and sprawl. Overall energy saving and air quality benefits likely.[47]
All Residents	Automobile Dependency	Large benefits. Significantly increases the viability of non-automotive modes.
All Residents	Economic	Mixed; location specific. Constrains some economic activities (such as freight delivery) but enhances others (such as tourism).

In recent years urban design, bicycle and pedestrian advocates, and neighborhood groups have argued that roadways are a public realm that should accommodate all users, and that overemphasizing automobile benefits in design is unfair. Advocates recommend alternative standards that reverse many current priorities in order to discourage traffic, reduce motor vehicle speeds, and emphasize other street functions, especially in urban commercial and residential areas. Called *neo-traditional* streets (when applied to new streets) and *traffic calming* (when applied to existing streets), these concepts include modified grid street networks, smaller scale streets and blocks, narrow lanes, tight corners, textured road surfaces, and greater integration of street users.[48] The ultimate goal of these efforts is to improve local and neighborhood environmental quality, and to encourage alternatives to

[47] Peter Newman and Jeff Kenworthy, *Cities and Automobile Dependency*, Gower, Aldershot, 1989.
[48] Gordon Shaw, "Impact of Residential Street Standards on Neo-Traditional Neighborhood Concepts", *ITE Journal*, July 1994, p. 30-32; D.T. Brennan, "Evaluation of Residential Traffic Calming: A New Multi-Criteria Approach," *Traffic Engineering and Control*, January 1994, p. 19-24. Tim Pharoah, *Traffic Calming Guidelines*, Devon County Council, UK, 1992.

driving. Table 7-6 summarizes the expected costs and benefits of traffic management based on the equity criteria described earlier (of course, actual impacts are situation specific and may differ significantly from these general estimates).

Table 7-7 summarizes these impacts of traffic management.

Table 7-7 **Traffic Management Benefits Summary**

	Non-Drivers	Low Income Drivers	Middle-High Income Drivers
User Market	Moderate Benefit	Small Cost	Small Cost
User Non-Market	Large Benefit	Small Cost	Small Cost
External Market	Moderate Benefit	Moderate Benefit	Moderate Benefit
Environmental	Large Benefit	Large Benefit	Large Benefit
Auto Dependency	Large Benefit	Large Benefit	Large Benefit
Economic	Mixed	Mixed	Mixed

This analysis indicates that traffic management provides equity benefits. Horizontal equity increases because the external impacts that drivers impose on others are reduced. Vertical equity increases because non-drivers (who tend to be socially disadvantaged) receive extra benefits. In many cities, low income urban neighborhoods could benefit most from traffic calming, indicating further potential vertical equity.[49] Although the financial impact of increased automobile operating costs is greater per mile for low income drivers than more affluent drivers as a percentage of income, low income households drive significantly less than wealthier households (Figure 7-1) and benefit more from reduced automobile dependency, so the vertical equity impacts among drivers is probably neutral.

7.6 Equity Analysis Conclusions

Most current analysis of transportation equity focus on a limited number of costs and benefits, consider only one equity variable, and ignore most long term effects. The significant external costs identified in this report indicates the potential for inequity. It is likely that people who drive a lot receive an unjustified subsidy from those who drive little

[49] David Engwicht *Reclaiming Our Cities and Towns*, New Society Publishers (Philadelphia), 1993.

or not at all. Since driving tends to increase with wealth and physical ability, subsidies to driving appear to be regressive. Underpriced driving is probably moderately unfair in terms of horizontal equity, neutral to moderately unfair in terms of income, and highly unfair in terms of need. People who are economically, physically, and socially disadvantaged are harmed by an automobile dependent transport system that does not meet their travel needs, and they tend to suffer a disproportionate share of external non-market costs use since they can afford fewer protections against traffic impacts.

The overall equity effects of price changes are largely dependent on how revenues are distributed, and could be highly progressive with respect to income while still providing overall benefits to all income groups. The income inequity impacts of price increases can be reduced by providing exemptions to low income households, increasing the quality and quantity of low cost alternatives, and returning revenue to low income households in the form of reduced regressive taxes, improved social services (including subsidies for transit and other low-cost travel modes), and rebates. Equity impact of specific regulations and pricing options must be evaluated individually, and should include analysis of how costs and revenues impact both low income and transportation disadvantaged people.

Transaction costs, such as economic changes that result in unemployment among traditional industries, tend to be inequitable with respect to income and social position since low income people have fewer resources to fall back on. These problems can be minimized or avoided by implementing changes gradually and predictably, through good planning, job development and retraining programs that improve employment opportunities for displaced workers.

Transit subsidies appear to be highly progressive, especially for services used by transit dependent riders. A test of the equity benefits of a particular transit program or project is the number of transportation disadvantaged and low income people who can and do use it.

Indications of transit system equity are whether fares are affordable, proximity of service to affordable housing, and the system's ability to transport people with disabilities. A commuter rail transit system that is accessed primarily by drivers (park-and-ride or kiss-and-ride) may provide no equity benefits and may be overall inequitable if it is subsidized with general taxes. However, this could change if affordable housing is developed within walking and bicycling distance of stations. Improvements for other transportation alternatives, including bicycling, walking and car pooling are probably also progressive. Traffic management strategies such as traffic calming and neo-traditional street designs that restrict automobile traffic and enhance bicycle, pedestrian and transit travel are probably moderately to highly progressive in most circumstances, although actual impacts depend on specific conditions.

Although this analysis does not attempt to quantify each cost and benefit, the estimates in this report make such an undertaking possible by determining the portion of a community's residents who are in each of the user classes, and estimating how both market and non-market costs are distributed among them. Some effects, such as automobile dependency, cannot currently be quantified and should be incorporated qualitatively.

8.0 Applications and Case Studies

The cost and elasticity estimates developed in this study are applied in this chapter to representative examples of transportation decision making.

8.1 Evaluating Transportation Demand Management (TDM) Savings

Many North American communities have TDM programs that encourage residents to use alternative travel options and reduce their driving. What are the benefits of such programs, and what resources should they receive relative to other transportation investments? The Oil-Smart Commute Performance Test offers an example for cost analysis.

Table 8-1 **Capitol Hill to Pioneer Square Trip Summary (Urban Peak Costs)**

	Mode	Dist-ance	Travel Time	Internal Cost	External Cost	Total Cost	Savings Over SOV
		miles	minutes	per trip	per trip	per trip	per day
1	Walk	2.2	41	$2.76	$0.01	$2.77	$4.58
2	Bike	2.75	10	$0.96	$0.06	$1.02	$8.07
3	Bike	3.5	16	$1.43	$0.08	$1.51	$7.10
4	Van Pool Driver	2.7	18	$2.99	$0.28	$3.27	$3.57
5	Van Pool Passenger	2.7	18	$1.95	$0.29	$2.24	$5.63
6	Van Pool Passenger, Walk	2.8	24	$2.30	$0.29	$2.58	$6.01
7	Van Pool Passenger, Walk	2.8	24	$2.30	$0.29	$2.58	$6.01
8	Van Pool Passenger, Walk	2.8	24	$2.30	$0.29	$2.58	$6.01
9	Van Pool Passenger, Walk	2.8	24	$2.30	$0.29	$2.58	$6.01
10	Bus Rider, Walk	3.2	35	$3.92	$0.96	$4.88	$0.35
11	Bus Rider, Walk	2.5	30	$3.65	$0.85	$4.50	$1.12
12	Car Pool Driver	3.4	15	$2.81	$0.61	$3.42	$3.28
13	Car Pool Passenger, Walk	3.3	20	$2.19	$0.62	$2.81	$4.49
14	Car Pool Passenger, Walk	3.3	20	$2.19	$0.62	$2.81	$4.49
15	SOV Driver	3.4	10	$3.00	$2.06	$5.06	$0.00
	Totals	**44.15**	**329**	**$37.05**	**$7.56**	**$44.61**	**$66.72**

Savings for each trip are calculated based on cost estimates in this report. Savings compared with an SOV trip are doubled to estimate savings per day. This illustrates one of four Commute Performance Test days.

The Oil-Smart campaign, an annual program spearheaded by the Seattle based Bullitt Foundation, encourages residents to use efficient travel modes. Dozens of community organizations participate in the campaign. During four days in March, 1994, 62 trips were monitored for a Commute Performance Test to determine the benefits of changing travel patterns. Of these trips, about half consisted of two links, such as walking to a park-and-ride lot to catch a van pool, so a total of 92 links were analyzed. Table 8-1 summarizes the distances, times, costs and savings for one day's trips. User (internal) and social (external) cost and saving estimates are derived from the estimates in this report.

The *external* cost reduction of these alternative modes is especially significant. For example, the calculated external cost of a trip from Capitol Hill to Pioneer Square is about $2.00 for an SOV driver, but averages only $0.39 per for other modes. If all 15 round trips that day were made by SOV the total external cost would have increased from about $15 to $60. Table 8-2 summarizes total costs and cost per mile for all trips in the test.

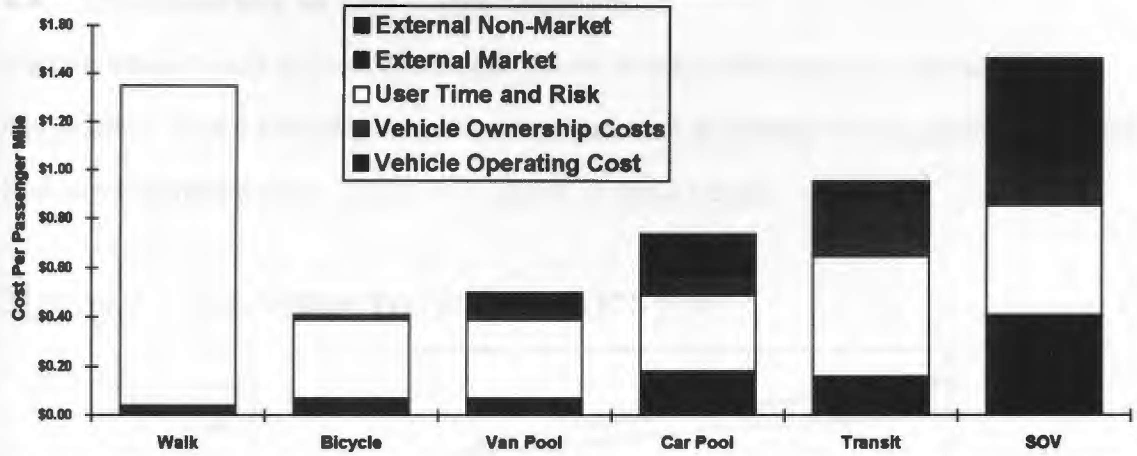
Table 8-2 **Commute Performance Test Summary Statistics**

Cost	**Totals**	**Walk**	**Bicycle**	**Van Pool**	**Car Pool**	**Public Transit**	**SOV**
Number of Trips	93	20	7	31	8	6	21
Total miles	489.9	14.4	45	269.1	52.9	40.2	68.3
User Costs	$255.35	$19.44	$17.47	$103.86	$26.33	$26.15	$57.98
User Costs Per Pass. Mile		$1.35	$0.39	$0.39	$0.50	$0.65	$0.85
Social Costs	$100.10	$0.05	$0.99	$31.00	$13.16	$12.19	$41.39
Social Costs per Pass. Mile		$0.00	$0.02	$0.12	$0.25	$0.30	$0.61
Total Costs	$355.44	$19.49	$18.46	$134.86	$39.50	$38.34	$99.38
Total Costs per Pass. Mile		$1.35	$0.41	$0.50	$0.75	$0.95	$1.46

This table summarizes costs per travel mode for the Commute Performance Test.

Figure 8-1 shows these costs broken down into major cost categories.

Figure 8-1 **Major Cost Categories per Mile by Mode**



This graph compares average travel costs per passenger mile for six modes used in the 1994 Oil Smart Commute Performance Test.

Significant Findings:

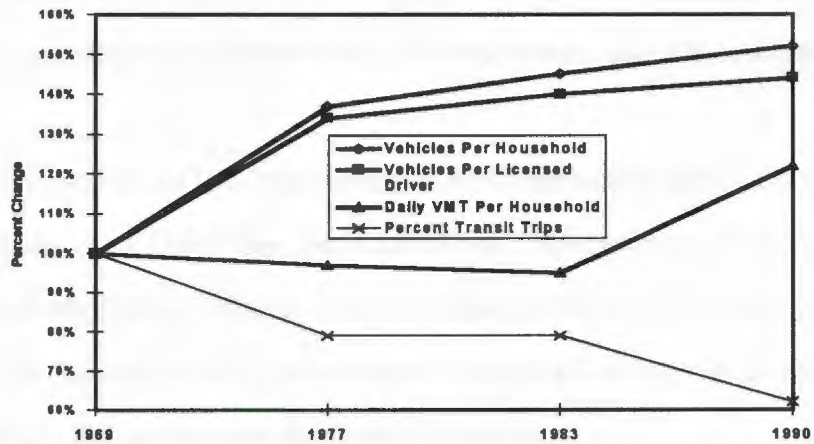
- Total savings by the 55 Oil Smart participants who used alternative modes were $467 compared with the same trips made entirely by SOV. This averages about $8.50 per person per day in savings.
- External costs of SOV travel average about 5 times greater per trip than other modes.
- The greatest savings *per trip* resulted from van pool riders who did not drive to their van pool stop. Total costs of van pool, car pool, and transit trips were sensitive to how the traveler got to their transit stop or rideshare meeting place.
- The greatest savings *per mile* resulted from bicyclists, since they had low operating and external costs but travel faster than pedestrians. The costs of bicycle and pedestrian trips are sensitive to the time value assigned to travel.

These findings indicate that significant investments in Transportation Demand Management programs are justified for programs that encourage use of alternative modes and reduce automobile use. They also indicate which modes and trip combinations offer the greatest total savings and the greatest potential for reducing external costs.

8.2 Price Impacts on User Travel Decisions

Current travel trends indicate continued growth in automobile use and automobile dependency. Motor vehicle driving has increased both absolutely and as a portion of total land travel in recent years. Figure 8-2 illustrates these trends.

Figure 8-2 **U.S. Vehicle Travel Trends, 1977-1990**[1]



Indicators show increasing automobile use and automobile dependency.

Although increased driving may result in part from demographic trends such as growth in female employment which increases commuting travel, other trends such as increased urbanization and improved communication and logistics could have compensated, resulting in no or negative growth in per capita driving. This increase in motor vehicle use is sometimes cited as proof of "America's love affair with the automobile." But an alternative explanation is that low user prices simply make driving too attractive for other modes to compete. As shown in Section 4.2, the out of pocket cost of driving is typically lower per mile than the cost of a bus fare. Studies described in Section 5.2 show that transport prices significantly affect travel patterns. Low priced driving supports a cycle of increased automobile use, automobile ownership and automobile dependency.

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[1] *Nationwide Personal Transportation Survey 1990: Summary of Travel Trends,* USDOT, 1993.

Consider the impacts of different transport prices (defined as the *perceived variable internal cost,* which includes user non-market costs such as travel time and risk) on typical user travel decisions. Assume that a resident has three shopping options: a local store accessible by a 1/2-mile walk, a small supermarket 2 miles away where prices average 15% lower than the local store, and a megastore 7.5 miles away where prices average 30% lower than the local store. Below is a comparison of the size of the shopping that would justify traveling to the farther stores between current and full-cost pricing.

The current price of Urban Off-Peak driving is $0.47 per vehicle mile. This includes vehicle operating costs, travel time, and internal risk. The *total* cost of driving (including fixed vehicle ownership and external costs) averages $1.06 per mile. Since walking has virtually no external costs, both price and total cost are $1.09 per mile under the same conditions. Table 8-3 summarizes the three trip options.

Table 8-3 **Current and Total-Cost Travel Price Impact on Store Selection**

	Local Store	Local Supermarket	Megastore
Round Trip.	1 mile walk	4 mile drive	15 mile drive
Savings over Local Store.	$0	15%	30%
Current trip price.	1 x 1.09 = $1.09	4 x 0.47 = $1.88	15 x 0.47 = $7.05
Current travel price premium over Local Store.	$0	1.88-1.09= 0.79	7.05-1.09=$5.96
Current shopping total to justify longer trip.	$0	0.79/15% = $5.27	5.96/30% = $19.77
Full trip cost.	1 x $1.09 = $1.09	4 x $1.06 = $4.24	15 x 1.06 = $15.90
Full-cost travel price premium over Local Store	$0	$4.24-1.09=$3.90	$15.90-1.09=$14.81
Full-cost shopping total to justify longer trip.	$0	$3.90/15% = $26.00	14.81/30%=$49.37

This table shows how underpricing discourages use of local services.

This analysis indicates that current underpricing gives users little economic incentive to walk 1/2 mile to a local store or shop at a local supermarket. At $0.47 per mile, the price of driving to a store 2 miles away appears almost the same as the price of walking to a store 1/2 mile away, and even a purchase under $20 justifies the 15 mile round trip to the Megastore. But when all costs are considered the shorter trips become more attractive, and the Megastore is only justified for a large shopping. This shows how prices that are below total costs skew user decisions to make longer and more frequent automobile trips.

Of course, other factors affect shopping habits. It can be difficult to carry big shopping loads without a car (although easy with a wagon or bicycle trailer), and large stores have a wider selection of goods. On the other hand, walking and shopping at local stores offers health, enjoyment and community contact benefits. Shopping is often part of linked trips, which reduces per trip costs, but linked trips tend to occur during peak periods when congestion and travel time values are high. This analysis indicates that much of the savings that individuals enjoy by shopping at a large, central store may be offset by incremental external transport costs, and the discrepancy between user price and total costs affects many travel decisions. Table 8-4 shows a similar analysis for home location decisions.

Table 8-4 **Current and Total-Cost Travel Price Impact on Home Selection**[2]

	Exurban Home	Central Home	Savings
Cars owned.	2	1	1
Annual Household VMT.	25,000	12,500	12,500
Annual user costs.[3]	$9,000	$4,500	$4,500
Annual external costs.[4]	$8,513	$4,792	$3,721
Total costs.	$17,513	$9,292	$8,221

Many trip decisions involve a tradeoff between travel costs and potential benefits. The more travel is underpriced the more marginal trips can be expected.

The Central Home reduces *external* costs by $3,721 annually compared with the Exurban Home, with a capitalized value of approximately $40,000 (the additional housing value that could be purchased if savings were invested in the mortgage). This implies that underpriced driving underprices exurban housing by at least this amount per unit. The

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[2] John Holtzclaw, "Explaining Urban Density and Transit Impacts on Auto Use," NRDC, 1990.
[3] Based on *Facts and Figures '93*, American Automobile Manufacturers Association (Detroit), p. 54.
[4] This assumes that Central vehicles are driven 33% Urban Peak, 33% Urban Off-Peak, and 33% Rural, Exurban vehicles are driven 23% Urban Peak, 33% Urban Off-Peak and 44% rural, and this driving incurs external costs of $0.61, $0.34 and $0.20 per mile respectively, as calculated in this report.

Central Home saves $8,221 annually in *total* driving costs over an Exurban Home, worth over $80,000 or more in capital value if used for mortgage payments.

Some economists argue that transport costs should be considered when calculating maximum mortgage payments.[5] Currently, the increased travel expenses associated with an automobile dependent home are not considered a cost by most lending agencies. As a result of underpriced driving and the omission of transportation expenses in mortgage budget analysis, home selection decisions are skewed toward automobile dependent, high travel cost houses, resulting in greater internal and external costs.

8.3 Marginalizing User Costs

Automobile owners typically pay approximately $0.21 per mile in fixed costs and $0.13 per mile in variable costs to drive. Fixed costs include about $0.08 per mile in vehicle insurance, licenses, registration, and vehicle ownership taxes, totaling about $1,000 per year.[6] Marginalizing these costs by paying them through additional fuel taxes or a mileage charge instead of fixed annual payments would allow automobile owners who reduce their driving to enjoy savings not currently available.[7] Various versions of this concept have been advocated by environmental and consumer organizations for years.[8] Table 8-5 shows the effect of an $0.08 per mile increase in vehicle operating costs.

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[5] Patrick Hare, *Making Housing Affordable by Reducing Second Car Ownership*, Patrick Hare Planning and Design (Washington DC), April, 1993. John Holtzclaw, *Using Residential Patterns and Transit to Decrease Auto Dependence and Cost*, National Resources Defense Council (San Francisco), 1994.

[6] Jack Faucett Asso., *Costs of Owning and Operating Automobiles, Vans and Light Trucks*, FHWA, 1992.

[7] Vehicle owners who currently reduce their driving by 100 miles only save about $13.00. By marginalizing these costs the same 100 mile reduction in driving would save $21.00.

[8] See for example M. El-Gasseir, *Potential Benefits and Workability of Pay-As-You-Drive Automobile Insurance*, for the California Energy Resources Conservation and Development Commission, June 1990.

Table 8-5 Estimated Annual VMT Impact of Marginalizing User Costs[9]

	Units	Urban Peak	Urban Off-Peak	Rural	Totals
Current Vehicle Operating Cost	$ per mile	0.15	0.13	0.11	
Current VMT	billions	460	920	920	2,300
Revised Price (+$0.08/mile)	per mile	0.23	0.21	0.19	
1-10 Year Elasticity		-0.2	-0.2	-0.2	
1-10 Year Revised VMT	billions	400	806	813	2,019

Changing insurance, registration, licensing, and taxes into variable costs would reduce overall driving at no extra cost to users, increasing overall transportation efficiency.

The estimated 281 billion miles per year that would be eliminated represent low value driving that users would forgo rather than pay an extra $0.08 per mile. Marginalizing these costs provides benefits to users (who enjoy savings not currently available) and society from reduced external costs. Table 8-6 shows the potential savings from this price change.

Table 8-6 Savings of Reduced Driving from Marginalizing Selected User Costs[10]

	Units	Urban Peak	Urban Off-Peak	Rural	Totals
Travel Reduction	billion VMT	60	114	107	281
Internal Saving	$/mile	0.71	0.71	0.64	
Total Internal Saving	$billions	$43	$81	$69	$193
External Savings	$/mile	0.61	0.34	0.20	
Total External Savings	$billions	$37	$39	$21	$97
Total Savings	*$billions*	*$80*	*$120*	*$90*	*$290*

Marginalizing costs that are currently fixed could save over $290 billion annually.

The analysis in Table 8-6 oversimplifies actual travel cost changes. In practice, some reduced automobile costs would be offset by increases in other types of travel. Table 8-7 recalculate the savings assuming that VMT reductions result 1/3 from reduced trips, 1/3 from reduced trip length, and 1/3 from mode shifts that are distributed equally among van pools, car pools, bus, bicycling, walking, and telecommuting. This more accurate analysis shows lower savings than in Table 8-6, but still worth over $200 billion annually.

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[9] Data from Chapter 3.1, and tables 4-3 and 5-5.

[10] Cost estimates from Table 4-3. This assumes that users enjoy savings proportional to their reduced driving. For example, depreciation costs would decline since they need to buy new cars less frequently.

Table 8-7 **More Accurate Savings of Reduced Driving from Marginalizing Costs**

	Units	Urban Peak	Urban Off-Peak	Rural	Totals
Eliminated Trips	billion VMT	20	38	36	192
Internal Savings	$/mile	$0.71	$0.71	$0.64	
Total Internal Savings	$billions	$14	$27	$23	$64
External Savings	$/mile	$0.61	$0.34	$0.20	
Total External Savings	$billions	$12	$13	$7	$31
Total Savings	*$billions*	*$26*	*$40*	*$30*	*$96*
Shortened Trips[11]	billion VMT	20	38	36	94
Internal Savings	$/mile	$0.47	$0.47	$0.41	
Total Internal Savings	$billions	$9	$18	$15	$42
External Savings	$/mile	$0.49	$0.30	$0.18	
Total External Savings	$billions	$10	$11	$6	$27
Total Savings	*$billions*	*$21*	*$31*	*$22*	*$74*
Shift to each of Six Modes	billion VMT	3	6	6	
Internal & External Savings[12]	$/mile	Varies	Varies	Varies	
Total Internal Savings	$billions	$5	$11	$8	$24
Total External Savings	$billions	$10	$8	$1	$19
Total Savings	*$billions*	*$15*	*$19*	*$9*	*$43*
Total VMT Reduction	billions	60	114	107	281
Total Internal Saving	$billions	$28	$56	$46	$130
Total External Savings	$billions	$32	$32	$14	$78
Total Savings	*$billions*	*$60*	*$88*	*$60*	*$208*

This analysis, more accurate than Table 8-6, shows annual savings over $200 billion.

Another way to let marginal user prices reflect a greater portion of automobile costs is to "Cash Out" free parking.[13] This means giving employees who currently receive free automobile parking the option of receiving its comparable cash value instead. Thus, employees who currently get a $30 to $60 per month subsidy for driving could receive an equal cash incentive for commuting by transit, ride share, bicycle or foot.[14] This offers potential benefits to employers from reduced parking supply costs, to employees who have the option of a financial bonus not currently available, and society due to reduced external costs such as congestion, pollution, and energy consumption. It is also equitable, since non-drivers are currently excluded from a valuable subsidy enjoyed by drivers. Donald

[11] Internal savings include user variable costs. External savings are all external costs except parking.
[12] Calculated in a separate spreadsheet.
[13] Donald Shoup, *Cashing Out Employer-Paid Parking*, Federal Transit Administration, December 1992.
[14] Non-drivers would actually receive a somewhat lower benefit because the cash is taxable while parking is exempt under current US income tax rules.

Shoup estimates that this measure alone could reduce solo commuting by 20%, and total vehicle travel by 3.3%, increase federal tax revenue by $1.2 billion annually.[15] This 76 billion VMT reduction would save an estimated $46 billion per year in external costs.[16]

The combination of maginalizing automobile insurance and registration, and Cashing Out employee parking could reduce current driving by an estimated 357 billion miles a year, or about 15% of total automobile travel, providing many billions of dollars in savings to users and society. These strategies involve neither increased costs nor coercion. The foregone trips represent low value travel that automobile users are willing to eliminate given greater choice. The only class of drivers likely to be disadvantaged are those who are currently uninsured, which is illegal in most states. Additional reductions in low value travel could be expected if user prices were increased to incorporate external costs. These estimates indicate that a significant portion of driving has negative net value (total benefits minus total costs), and that society would benefit significantly from these price changes.

8.4 Critiquing Transportation Investment Models

A number of benefit cost models are used for the economic analysis of transport investments.[17] These models compare project benefits (travel time savings, accident reductions, and vehicle operating savings) with financial costs (land acquisition, construction, and maintenance). They specify how the benefits of generated traffic should be measured, and emphasize that all costs must be considered.

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[15] Donald Shoup, "Cashing-Out Employer-Paid Parking; An Opportunity to Reduce Minimum Parking Requirements," *Journal of the American Planning Association*, Forthcoming, June 1994.

[16] Based on Urban Peak external costs of $0.61 per mile, from Table 4-2. Although not all commuting is Urban Peak, mode shifts are most likely under these conditions because the most options are available.

[17] Examples include the MicroBENCOST computer program developed for the USDOT, and the COBA (COst Benefit Analysis) model developed by the British Department of Transport.

As discussed previously, generated traffic and external costs are often ignored in transportation planning. Both omissions skew the results in the same direction, making road expansion projects appear more attractive and other options such as demand management and public transit investments appear less attractive. Another significant omission in most current modeling is the use of short term point elasticity values rather than dynamic values that vary over time.[18] Long term elasticities are usually much greater than short term elasticities. The justification often used for this exclusion is that the necessary data are not available, but that is untrue.

To test the effect of omitting generated traffic in transportation decisions, researchers Robert Johnston and Raju Ceerla used a conventional four-step traffic model to evaluate transport investments in Sacramento, California, and then evaluated the same investments with a newer model that incorporates feedback from generated traffic.[19] The model that incorporates generated traffic changed the ranking of options compared with the standard model. The ranking of No Build, Light Rail, and Road Pricing increased with feedback, while building additional highway capacity becomes less attractive. Johnston and Ceerla did not incorporate estimates of external costs in their analysis, but doing so would certainly increase the calculated costs and decrease the benefits associated with projects that add roadway capacity. Williams and Lam reached similar conclusions concerning the impacts of ignoring generated traffic,[20] and also point out that highway investments can impose external costs in terms of reduced transit service efficiency.[21]

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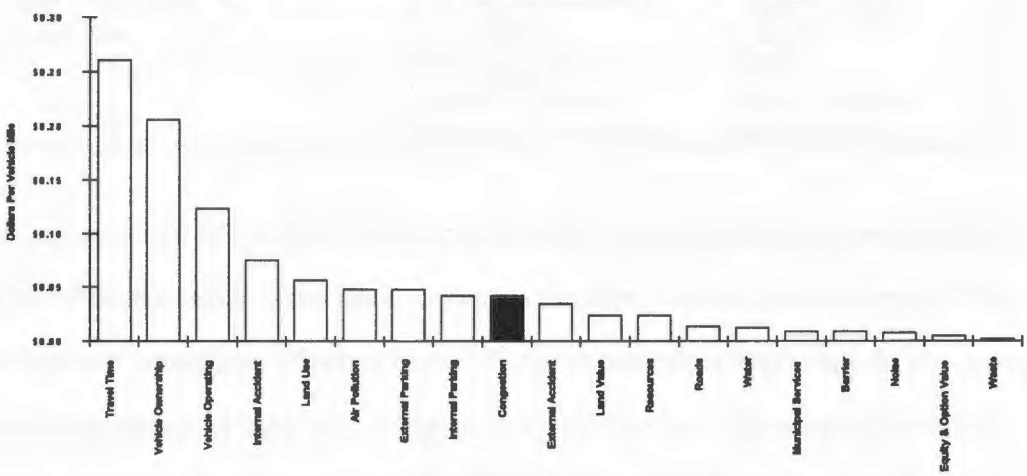
[18] J.M. Dargay and P. B. Goodwin, "Estimation of Consumer Surplus with Dynamic Demand Changes," in *Proceedings of European Transport Forum*, PTRC, Sept. 1994.
[19] Robert Johnston and Raju Ceerla, Institute of Transportation Studies, University of California (Davis), "A Comparison of Modeling Travel Demand and Emission with and Without Assigned Travel Times Fed Back to Trip Distribution" Submitted to the *Journal of Transportation Engineering*, April 11, 1994.
[20] H.C.W.L. Williams and W.M. Lam, "Transport Policy Appraisal With Equilibrium Models I: Generated Traffic and Highway Investment Benefits," *Transport. Research B*, 28/5, pp. 253-279, 1991.
[21] H.C.W.L. Williams and W.M. Lam, "Transport Policy Appraisal With Equilibrium Models III: Investment Benefits in Multi-Modal Systems" *Transportation Research B*, 28/5, pp. 293-316, 1991.

Generated traffic increases virtually all external costs, including air pollution, nose, energy consumption, parking demand, congestion on local streets, urban sprawl, and automobile dependency. Projects that reduce overall vehicle use provide benefits in terms of external cost savings that are not recognized in current models. Only if economic analysis incorporates total external costs including impacts of generated traffic can society be sure that projects being funded actually provide overall benefit.

8.5 Evaluating Congestion Reduction as a Transport Improvement Priority

The cost estimates in this report can be used to compare the relative significance of transport costs. Figure 8-3 shows automobile costs ranked by magnitude.

Figure 8-3 **Average Automobile Costs Ranked by Magnitude**



Since user travel time is the highest ranking cost, it could be argued that projects which increase travel speeds offers significant potential benefits. However, as discussed in Section 5.4, individuals tend to maintain a constant travel time budget, so in practice the benefits of most investments that increase travel speeds translate into shifts in activity locations, and are capitalized into real estate values as residents travel longer distances to work, school, shopping, and recreation centers.

Traffic congestion is the *additional* travel time imposed on society above optimum traffic volumes. Although congestion is often assumed to be our greatest transportation problem, the reduction of which consumes most transport investment funds, this analysis indicates that overall it is only a middle-range cost. More importantly, traffic congestion is a relatively small cost compared with the total of costs that typically increase in response to efforts to accommodate more vehicle traffic. Of 17 transport costs, two (travel time and congestion) tend to be reduced by increased traffic capacity and speeds, while 15 tend to increase, as shown in Table 8-8.[22]

Table 8-8 **Transportation Costs Affected by Increased Roadway Capacity**

Costs Typically Reduced by Increased Road Capacity	Costs Typically Increased by Increased Road Capacity[23]	
	Vehicle Costs	Parking
	Road Facilities	Accidents
User Travel Time	Municipal Services	Equity & Option
Congestion	Air Pollution	Barrier Effect
	Waste generation	Noise
	Land Use Impacts	Water Pollution
	Resource consumption	Roadway Land Use

A number of urban economists have concluded that current roadway investment policies and failure to internalize costs leads to overinvestment in roads both in terms of financial costs and as a percentage of urban land.[24] These perspectives imply, but do not prove, that traffic congestion is an overrated problem. To prove this it is necessary to compare potential benefits of congestion relief with other possible investments, which is not

[22] Some projects are intended to improve roadway safety, but drivers frequently respond by driving faster, resulting in no change in accidents. See Robert Davis, *Death on the Streets*, Leading Edge (London), 1992. Recent research on highway safety improvements by Mike Kawczynski P.Eng. of MAC Engineering for the B.C. Ministry of Transportation and Highways found the same results.

[23] Although reduced traffic congestion and stop-and-go driving decrease per mile energy consumption, air pollution, and vehicle operating costs, current estimates indicate that these savings are overwhelmed by overall increases in driving. See Hansen, et al., *The Air Quality Impacts of Urban Highway Capacity Expansion: Traffic Generation and Land Use Change*, Institute of Transportation Studies, UCB (Berkeley), 1993; Newman and Kenworthy, *Cities and Automobile Dependency*, Gower Press, 1989.

[24] Takahiro Miyao and Yoshitsugu Kanemoto, *Urban Dynamics and Urban Externalities*, Harwood Academic Publishers (NY), 1987, pp. 77-87.

possible based on data in this study. However, additional factors also indicate that current congestion reduction benefits may be lower than is often assumed, which further implies that transport planning and investments overemphasize congestion relief. As discussed in the previous section, most economic estimates of traffic congestion *overstate* the potential of reducing this cost because traffic congestion maintains a self-limiting equilibrium. Efforts to accommodate more trips leading to generated traffic. Increased congestion forces individuals and communities to limit their driving and use substitutes, which include shifts in route, mode, time destination, and alternatives such as faxes and delivery services. Traffic congestion does not stop economic activity, it simply causes individuals to choose a marginally more expensive alternative.

Efforts to reduce traffic congestion can have perverse effects. Kenneth Small suggests that efforts to reduce traffic congestion by increasing road capacity can incur external costs by diverting travel from public transit to automobiles, therefore reducing the efficiency of the transit system (reduced economies of scale) while the generated traffic reduces or eliminates any long term congestion reduction benefits.[25] In other cases, road improvements that create more direct routes can divert traffic from circuitous but less congested roads, resulting in slower travel for everyone.

Several studies (some mentioned in Chapter 3.5) estimate current and future congestion based on trend analysis, often with alarming conclusions. The US Congress's Office of Technology Assessment found significant problems with some of these studies, including methodological mistakes in calculating roadway capacity, and the failure to recognize that traffic congestion tends to be self-limiting.[26] Although some indicators show growing traffic congestion, others, such as declining urban commute travel times and increased

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[25] Kenneth Small, *Urban Transportation Economics*, Harwood (Chur), 1992, p. 115.
[26] *Saving Energy in U.S. Transportation*, OTA (Washington DC), July 1994, p. 111-122.

average highway speeds in many areas, show contradicting trends. Rather than assuming that a community's primary transport problem is congestion, it would be better to define the problem as: *Transportation is too expensive in terms of all costs*. This includes travel time (which incorporates congestion delays), other user costs, plus all costs to society.

Does Traffic Congestion Significantly Burden the Local Economy?
Empirical evidence supports the hypothesis that predictable traffic congestion imposes a relatively minor constraint to economic activity, provided that other transport options are available. Cities such as Hong Kong, Tokyo, New York, London and Paris, have extreme levels of traffic congestion. Similarly, traffic congestion is inescapable in fast growing suburban and exurban communities due to high levels of automobile dependency and use.[27] These indicate that a positive correlation exists between traffic congestion and local economic activity. Of course, this does not mean that congestion *contributes* to economic growth, but it indicates that congestion does not significantly limit economic activity, economic development, or property values. Although traffic congestion is clearly an economic cost, it does not appear to be a significant burden, especially if alternative access options, such as telecommunication, subways and local shops and services are available.

This study's cost estimates can help identify the overall optimal congestion reduction strategies. Pricing appears most cost effective because it reduces congestion, reduces total vehicle travel thereby reducing total external costs, and raises revenue. Programs to reduce traffic congestion by increasing road capacity appear to be least cost effective, because in addition to their direct financial, social and environmental costs they accommodate additional vehicle use that increases total external costs, and as described earlier the improvement they provide degrades over time due to generated traffic. Non-pricing TDM programs (promotion and support of alternative modes, and land use

[27] Robert Cervero, *America's Suburban Centers: The Land Use-Transportation Link*, Unwin Hyman, 1992. Joel Gerreau, *Edge City*, Doubleday, 1992.

management) is probably intermediate between pricing and road capacity programs, and appears to be highly variable depending on specific circumstances.[28] Although the existence of generated traffic and external costs does not exclude the possibility that some capacity expansion projects are still cost effective, it is a more rigorous standard which would probably indicate that costs exceed benefits of many approved projects.

As discussed in Chapter 5, traffic tends to fill available road capacity due to generated traffic, but grows less or not at all if new capacity is not added. Some people argue that road capacity *must* increase to accommodate population growth.[29] It is true that traffic increases with urban sprawl and poorly planned development. On the other hand, more population within a given area (increased density) can increase the accessibility of services, such as shops and schools, and increase mode choices, reducing per household automobile use and dependency, and per capita road requirements.[30] Development practices that take advantage of travel reduction opportunities can avoid the need to increase road capacity.[31]

This analysis returns us to consideration of the meaning of transportation. If society defines transport simply as *vehicle travel* it is easier to conclude that costs decline with road building, and conventional planning and investment programs are justified. If transportation is defined as *access*, then roadway expansion projects may actually increase total transport costs by increasing urban sprawl, automobile dependency and use, and associated social and environmental impacts. Investment projects must be evaluated

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28 In his book *Stuck in Traffic (*Brookings Institute, 1992) Anthony Downs argues that such programs are popular *because* they are relatively ineffective. However, they do seem to have a marginal effect by reducing some market and social barriers to travel pattern changes.

29 *Myths and Facts about Transportation and Growth*, Urban Land Institute (Washington DC), 1989.

30 See Chapter 3.14 for discussion of the effects of sprawl on transportation.

31 For information on designing communities to reduce automobile dependency see John Holtzclaw's "Using Residential Patterns and Transit to Decrease Automobile Dependence and Costs," National Resources Defense Council (San Francisco), 1994; Steve Weissman; Judy Corbett, *Land Use Strategies for More Livable Places*, California Environmental Protection Agency, 1992; Rebecca Ocken *Site Design & Travel Behavior: A Bibliography*, 1000 Friends of Oregon (Portland), 1993.

according to total costs, including long-term impacts on land use and automobile dependency, to insure that they provide net benefits.

Framing the Congestion Cost Question
If you ask people, *"Do you think that traffic congestion is a significant problem that deserves significant investment?"* most would probably answer yes. If you ask them, *"Would you rather invest in road capacity expansion or use lifestyle changes, such as increased urban density and more use of walking, bicycling, car pooling and public transit to solve congestion problems?"* a smaller majority would probably choose the road improvement option. These are essentially how choices are framed by conventional transportation plans. But if you presented a more realistic description of our choices by asking, *"Would you rather spend a lot of money increasing road capacity that will provide only moderate and temporary reductions in traffic congestion and will increase personal, municipal, social and environmental costs, encourage urban sprawl, raise rural property values, and leave a legacy of automobile dependency to future generations, or would you rather modify and accelerate lifestyle changes that will occur anyway (increased urban density and multimodalism) over the next few decades to avoid these problems?"* a majority would probably choose alternatives to more road building.

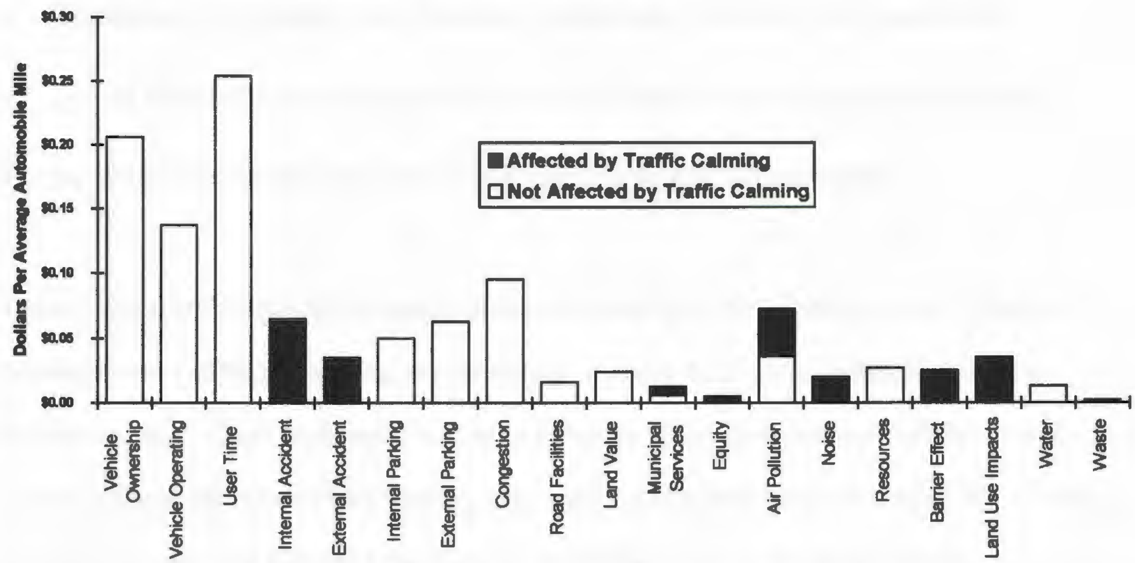
8.6 Evaluating Traffic Management Benefits

As discussed in section 6.5, a conflict exists in roadway design between maximizing traffic flow and protecting local environmental quality. Increased traffic volume and speed:

- Require more land for streets and parking at the expense of pedestrian and bicycle facilities, and other public spaces.
- Increase risk of accidents between automobiles and other road users.
- Increase barriers to pedestrian and bicycle movement.
- Increase noise, air pollution and dust.
- Increased automobile dependency
- Increase urban sprawl.

Transport cost analysis can help determine the optimal allocation of resources between motor vehicle traffic and local environmental quality. Current local traffic planning tends to overestimate the benefits of increasing road capacity, and underestimate external costs as previously discussed. Figure 8-4 illustrates estimated costs that are likely to decline due to traffic calming and neo-traditional streets, assuming that the same amount of driving takes place but at lower speeds.[32] These costs average $0.19 out of $1.37 total cost per vehicle mile, and may be much higher in many urban areas.

Figure 8-4 **Costs Reduced by Traffic Calming**



Automobile costs that traffic calming programs are likely to reduce.

This analysis indicates that local environmental and social costs can be substantial compared with other transportation costs.[33] Current traffic planning and funding ignore many of these costs, so automobile traffic improvements tend to occur at the expense of local environmental and social benefits. Since motor vehicle traffic imposes these costs, it

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[32] Based on an average of Urban Peak and Off-Peak costs, with noise and barrier effect costs doubled to represent higher impacts on neighborhood streets.

[33] If anything, this underestimates potential benefits, since neo-traditional neighborhoods can also provide traffic congestion and user costs savings by reducing automobile dependency.

is both equitable and efficient to use motor vehicle user funds to implement traffic calming and related projects to reduce impacts and improve neighborhood environmental quality.

8.7 Least-Cost Transportation Planning

Least-Cost planning is a concept used in utility planning that is now being applied to transportation investment decisions. Despite being relatively new, Least-Cost transport planning is required in California at the state level,[34] in Washington State at the regional level,[35] and is recommended by several analysts.[36] Least-Cost planning includes:

- Consideration of supply and demand management options on an equal basis.
- Use of standard measurements of costs and benefits for evaluating investments.
- Selection of projects and programs according to cost effectiveness.

Least-Cost transportation planning means, for example, that Transportation Demand Management (TDM) programs are compared equally with investments that increase facility capacity. This represents a change because TDM programs currently receive limited consideration and less funding than general roadway improvements. Researchers Caroline Rodier and Robert Johnston point out that current transport funding formulas tend to reward regions that demonstrate increased travel demand and tend to give fewer resources to communities that successfully reduce demand.[37] They describe a method for

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[34] *California Transportation Energy Analysis Report (Draft)*, California Energy Comm., Feb. 1994, p. 1

[35] Cy Ulberg, Jane Meseck Yeager and Matthew Hansen, *Least-Cost Planning Implementation*, Washington State Transportation Center (Seattle), 1995.

[36] Ruth Steiner, *Least Cost Planning for Transportation; What We Can Learn*, TRB 1993 Annual Meeting; Sheets and Watson, *Least Cost Transportation Planning: Lessons from the Northwest Power Planning Council*, Bullitt Foundation (Seattle), January 1994; Nelson and Shakow, *Applying Least Cost Planning to Puget Sound Regional Transportation*, Bullitt Foundation, (Seattle), February 1994; Michael Grant, *A Methodology for Evauating Cross-Modal Transportation Alternatives*, Office of Intermodalism, USDOT (Washington DC), 4 August 1994.

[37] Caroline Rodier and Robert Johnston, *Incentives for Local Governments to Implement Travel Demand Management Measures*, Institute of Transportation Studies, UCD (Davis), October 1994.

calculating the financial benefits of deferring a highway capacity project and apply it in a case study in the Sacramento, California region. They estimate that local governments there could justify spending $37 million per year in TDM programs if it delayed future anticipated roadway expenditures for seven years. Even greater demand management expenditures could be justified if external costs are incorporated into the analysis.

As an example of Least-Cost planning, consider a transport problem facing Olympia, Washington. Access between the city's downtown and the Westside is limited by a bottleneck at the Fourth and Fifth avenue bridges.[38] Together the two bridges can carry approximately 1,800 vehicles per hour in each direction. A $10.4 million widening project has been proposed to increase peak bridge capacity by 1,149 vehicles. This would require annual payments of $838,100, for a cost of $1.40 per additional peak period automobile one-way trip.[39] As discussed in Chapter 5, increased road capacity can:

1. Shorten some trips by allowing more direct routes. Although shorter trips usually reduce external costs, downtown Olympia is very sensitive to traffic impacts (congestion, noise, barrier effect, etc.) so this is unlikely to provide overall savings.
2. Encourages some longer trips which increase external costs.
3. Generates some new trips. This increases external costs, especially due to downtown Olympia's sensitivity to increased traffic.
4. Increase peak periods trips. This increases costs, including congestion on other roads.
5. Encourages mode shifts from transit to driving.

The additional external costs of these effects can be calculated. Assume that the 1,149 additional peak period trips are equally divided among effects 1-4, (effect 5 is not significant in this case due to low transit use) times two peak periods per day, times 260

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[38] Gilbert McCoy, Kristine Growdon and Brian Lagerberg, *Applying Electrical Utility Lease Cost Planning Approaches to the Transportation Sector*, Washington State Energy Office (Olympia), 1993.
[39] Assuming 7 percent interest on 30-year bonds, and 260 annual work days.

annual work days, equals approximately 150,000 annual trips changed per effect (1,149 ÷ 4 x 2 x 260 = 149,370), as summarized in Table 8-9. The total cost to society of this proposed project includes $838,100 in construction costs and $1,434,000 in external costs, totaling over $2.2 million per year, $3.77 per additional trip, or over $7.50 per additional round trip commute. The specific values used are for illustrative purposes only, but they indicate the significant costs imposed on society from increased urban driving.

Table 8-9 **External Traffic Cost Impacts from Increased Bridge Capacity**

Effect	Peak Mileage Change	External Cost Per Mile	Total Additional External Cost
1. Average trip length reduced by 4 miles.	- 600,000	None[40]	$0
2. Average trip length increase by 4 miles.	+600,000	$0.61[41]	$366,000
3. Generated trips, average 8 miles.	+1,200,000	$0.61	$732,000
4. Shift from off-peak	+1,200,000	$0.28[42]	$336,000
5. Mode change.	None	None	None
Totals	2,400,000		$1,434,000

Increasing road capacity provides user benefits and external costs from increased total motor vehicle use. Additional costs should be considered in investment evaluation.

The city could consider demand management options rather than invest in increased capacity. The components of a TDM program depend on specific geographic and demographic conditions, but might include improvements to transit, bicycle and pedestrian facilities, and incentives to reduce peak period driving. Once the costs and effectiveness of specific TDM options are estimated, a supply curve is developed based on the cost per vehicle trip reduced across the bridge. The most cost effective options would be chosen until a goal (such as 1,149 peak hour trips reduced) or budget constraint is reached. The $838,100 annual cost of increasing bridge capacity could fund a respectable TDM program. The $2.2 million total annual cost could fund an outstanding TDM program. The

[40] Due to the sensitivity of downtown Olympia to traffic impacts, described above.
[41] Average automobile external Urban Peak external costs from Table 4-3.
[42] Difference between average automobile Urban Peak and Urban Off-Peak external costs.

TDM option should be chosen instead of the capacity construction option if expenditures less than the $2.2 million total would reduce peak period driving along that corridor. Note that this estimate only considers costs on one corridor. Reduced traffic on other roads would provide additional benefits that could justify even greater TDM expenditures.

8.8 Evaluating Electric Vehicle Benefits

There is considerable interest in alternative automobile engines and fuels to reduce environmental costs. Alternative fuels, especially electric vehicles, are often cited as solutions to the environmental impacts of our current transportation system. The costs developed in this report can be used to evaluate these options from an overall economic perspective. For simplicity sake this analysis focuses on electric vehicles, although a similar analysis could be performed for a variety of fuels.

As discussed in specific cost chapters, electric vehicles reduce but do not eliminate several costs. For example, local air pollution may be avoided but a portion of electric generation capacity comes from fossil fuels which produce global air pollutants. Similarly, although engine noise is greatly reduced, electric vehicles still emit road-tire noise. Cost effects are summarized in Table 8-10.

Table 8-10 **Fuel Type Effects on Transportation Costs**

Costs Typically Reduced in Electric Vehicles	Costs Unaffected by Electric Vehicles	Costs Typically Increased in Electric Vehicles
Air pollution, Noise Water pollution, Waste Resource (energy) consumption externalities	User travel time, Congestion Accidents, Parking Land value, Barrier effect Equity & Option, Land use impacts Municipal services	Vehicle ownership Vehicle operating Road facilities[43]

This table shows how costs typically differ between gasoline and electric vehicles.

[43] Although road facility costs do not actually increase, electric vehicle use does not contribute to dedicated fuel taxes so their subsidy is greater based on the cost analysis framework used in this report.

Three types of electric vehicles are considered:

1. **Standard Electric.** This is based on current electric car ownership and operating costs, which are higher than a standard automobile. This uses the electric vehicle costs defined earlier in this report.

2. **Cheaper Electric Car.** This is based on the assumption that these costs will decline in the near future due to increased production. Ownership and operating costs are equal that of an average automobile, and other costs are as defined earlier for an electric vehicle.

3. **Neighborhood vehicle.** These are small, inexpensive, low power, low speed electric vehicles intended for local urban travel.[44] These are estimated to reduce all costs except travel time, congestion, and road services (policing, planning, etc.) by 50%.[45]

Figure 8-5 shows the total costs of these four vehicles by major category. Although Standard Electric Cars reduce some non-market externalities, their current high ownership and operating costs make them slighly more expensive overall. Of course, these average values underestimate the cost differential in urban areas with high noise and local air pollution costs.[46] Assuming that reduced future production costs will make Cheaper Electric Cars available, overall savings are possible. However, electric cars do not reduce many external costs of driving, including parking subsidies, accident risk, urban sprawl, or inequity. To significantly reduce total costs requires an inexpensive, efficient, safe, small vehicle that does not encourage urban sprawl, such as the Neighborhood Car.

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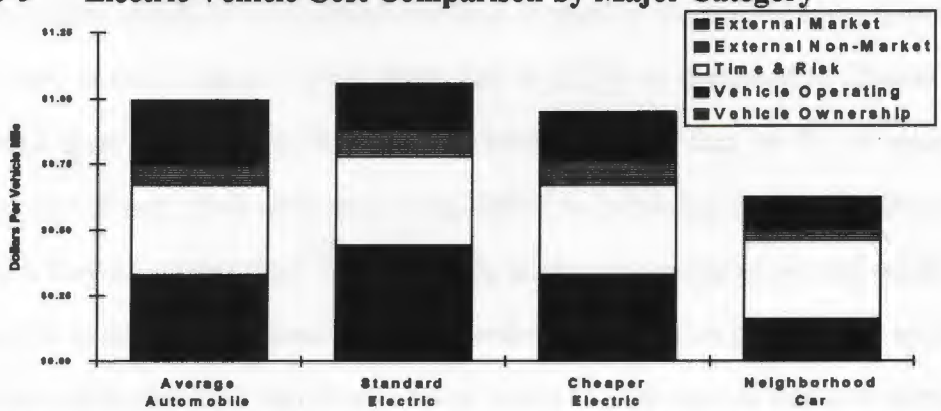
[44] Daniel Sperling, "Prospects for Neighbohood Electric Vehicles," *Transportation Research Record 1444*, 1995, p. 16-22.

[45] This estimate is somewhat arbitrary since specific performance and cost data are not available.

[46] Roland Hwang, et al., *Driving Out Pollution: The Benefits of Electric Vehicles*, Union of Concerned Scientists (Berkeley), 1994 estimate lifetime benefits of electric vehicles at $17,570 in So. California.

Figure 8-5 **Electric Vehicle Cost Comparison by Major Category**



This graph compares cost categories of three electric vehicles and an average automobile based on the assumptions stated above.

8.9 Critiquing Taxation Report

The study *Transportation Taxation and Competitiveness*, published by the Transportation Association of Canada (TAC) in September 1993 examines the economic impacts of Canadian transport taxes.[47] It concludes that road transportation is overtaxed because motor vehicle tax revenues are not spent entirely on roadway facilities. This conclusion has been widely publicized by industry lobbying groups to justify lower fuel taxes and increased expenditures on driving.

This argument can be analyzed using the cost estimates from this report. Current Canadian automobile fuel taxes average $0.263 per litre Canadian, or about U.S. $0.84 per gallon. Based on average automobile fuel efficiency of 21 mpg, this equals about $0.04 per mile. Automobile owners also pay annual registration fees and taxes that might increase average user payments to as much as $0.05 per mile. Assuming that Canadian average external costs of driving are comparable to the $0.32 per mile estimated for the U.S. (Table 4-3), automobile user taxes cover only about 16% of external costs.

[47] TAC membership includes transport industries and agencies.

Not all fuel taxes should be considered user fees. A portion are general taxes (Goods and Services Tax, or GST, and Provincial Sales Tax, or PST). As discussed in Chapter 1, broad based taxes such as these should not be considered user fees, or the tax system would become absurd. If all sales taxes were limited to providing services for the sector from which they originated there would be little funding for essential general public services such as education, planning, and law enforcement. Taxes paid on hats would be targeted for public hatracks, and theater taxes would be dedicated to popcorn subsidies. Excluding this revenue, fuel taxes cover only about 13% of estimated external costs.

These estimates suggest that motor vehicle user payments are low compared to the costs motor vehicles impose on society. This contradicts the TAC report's conclusions and recommendations. Although the report acknowledges the potential of significant external costs, the authors make no effort to incorporate them in the analysis. Their justification is,

> *"...most analyses to date readily acknowledge that data quality problems and theoretical limitations (e.g., pavement deterioration models) make it difficult to accurately quantify the extent of cost recovery."*[48]

The TAC report argues that minimizing prices will improve national productivity and competitiveness. However, as discussed in Section 6.1, economic efficiency is optimized when prices reflect marginal costs. Current low taxes reduce the nation's overall economic efficiency and competitiveness by diverting resources from other sectors. Like other lobbying organizations, TAC uses data selectively to support arguments for increased subsidies without consideration of economic efficiency or fairness.

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[48] Denis Lacroix, Jan Bowland and Frank Collins, *Transportation Taxation and Competitiveness*, TAC (Ottawa), Sept. 1993, p. 44.

9.0 Conclusions and Recommendations

This chapter summarizes this report's major conclusions and provides recommendations for improving the efficiency and equity of our transportation system. These conclusions won't surprise readers familiar with recent literature on transportation economics or policy issues. Other books, reports and articles make similar points.[1] This study augments previous documents by providing specific cost estimates and an analysis framework that can be applied to analyze policies and programs.

The first conclusion of this study is that the high levels of automobile use found in North America and other high consuming countries are not essential, and probably reduce overall economic success or personal happiness compared with transport systems that provide more travel options, reduce external costs (accidents, pollution, congestion), avoid urban sprawl, minimize financial costs, and increased overall economic efficiency. Another important conclusion of this study is that driving is significantly underpriced compared with total costs. Two factors contribute to this: some costs are fixed and others are external. Variable user costs (including vehicle operating expenses, travel time, and accident risk) comprise less than half of total costs. About a quarter of total costs are fixed, and a third are external. These ratios vary depending on travel conditions and vehicle types, but the basic relationships are consistent for virtually all driving.

The benefits of motor vehicle travel are substantial, but these are squandered when society succumbs to the temptation to underprice. Automobile owners have no incentive to limit driving to trips in which benefits exceed total costs. This results in wasteful travel in which

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[1] Examples include Elmer Johnson's *Avoiding the Collision of Cities and Cars*, American Academy of Arts and Sciences (Chicago) 1993; Deborah Gordon, *Steering a New Course*, Union of Concerned Scientists (Cambridge) 1991; S. Nadis and J. Mackenzie, *Car Trouble*, Beacon Hill (Boston) 1993.

a dollar is often spent to provide fifty cents worth of benefit. Other problems such as congestion, pollution, and community degradation become constraints to traffic growth.

According to conventional wisdom traffic congestion is our greatest transportation problem. This justifies current planning and funding practices that emphasize projects to increase road capacity. This study provides a different perspective. According to estimates developed here, congestion is a moderate problem (cost). Other costs which increase when automobile use grows are greater overall. Underpriced driving encourages overuse, forcing congestion to be self limiting. As expressed by Moore and Thorsnes,

> *"No rational concert promoter would decide how big to build a stadium based on the number of people who would come to see the Greatful Dead if the tickets were free. But that is often how transportation planners decide highway capacity: they estimate how many trips would be make on an unpriced facility, then try to build a facility big enough to accommodate that number of trips."*[2]

Efforts to reduce congestion by increasing road capacity creates more traffic and increases automobile dependency in the long run. Transport programs should be evaluated according to how well they improve access at the lowest total cost to users, society, and the environment. Only by considering all costs can society be confident that transport investments really provide net benefits.

There is no single solution to our current transportation problems. Neither improved transit service, increased bicycling and walking facilities, "smart" highways, nor less polluting vehicles *alone* can reduce the inefficiencies of our transport system while the price of driving is so low. Solutions to congestion that increase road capacity and traffic speeds exacerbate transportation problems. Such solutions accommodate existing inefficiencies and inequities, and increase the total amount of driving in the long term.

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[2] Moore & Thorsnes, *Transportation/Land Use Connection*, American Planning Association, 1994, p. 57.

Making user prices reflect marginal user costs is the key to encouraging more efficient transport, but increasing prices alone is only half the solution. Changes in land use patterns, planning, investment policy, and personal habits are also needed. Our current transportation system encourages every driver to own a "personal" car. A more efficient and equitable transportation system would provide users with more travel choices, and provide incentives to use each mode for what it does best.

9.1 Costs and User Pricing

As stated above, a primary conclusion of this study is that transport, especially automobile use, is underpriced with respect to total costs. External costs that tend to be ignored during transportation planning and investment decisions include parking, congestion, accidents, municipal service costs, land use impacts, roadway land value, environmental degradation, and social impacts. Urban peak driving incurs the greatest external costs per mile, but external costs of driving under other conditions are also significant.

The problem is not only that costs are externalized. Although automobile ownership costs are a major portion of most household budgets, automobile operating costs are typically lower per mile than a local bus fare. Automobile owners have little financial incentive to limit their driving or use other modes. This price structure provides an incentive to maximize driving in order to "get your money's worth" from high fixed costs.

Transportation costs affect economic productivity and development. As discussed in Section 6.2, this does *not* justify underpricing or subsidies. Although underpriced driving provides many visible benefits, these are mostly transfers. Each dollar of benefit from underpricing creates at least a dollar's worth of economic loss somewhere. Underpricing encourages inefficient use of resources that reduces economic efficiency. Although a particular transport improvement may contribute to development in a region or community, there is no economic reason that the facility users shouldn't pay the facility's cost. In practice, most transport improvements provide only marginal benefits in countries that already have extensive road, railroad, and shipping networks.

"Raise My Prices, Please!"

There is a vivid and highly emotional vocabulary to describe overpricing. A person who paid too much is said to have been "gouged," "gypped," or "fleeced." It is easy to demonstrate that overpricing reduces economic efficiency, and tends to be inequitable, so overpricing is a favorite issue for economists and policy analysts. Countless political campaigns, debates, policies, and programs focus on eliminating overpricing.

Underpricing has a similar negative impact. Underpricing leads to economic inefficiency and unfairly imposes costs on individuals and society. It can have significant negative social and environmental impacts. But we are unlikely to hear a popular cry, *"Raise my prices, please."* Low prices may be acknowledged intellectually as an economic problem, but because impacts are dispersed and nearly invisible, it seldom creates emotional fervor. Educating policy makers, planners, and the public about problems created by underpricing is a key challenge to developing an efficient and equitable transportation system.

Although it is often claimed that Americans have a love affair with the automobile, high levels of automobile dependency and use are more accurately explained by decades of low prices and skewed investments. At one time society may have benefited from increased motor vehicle use due to economies of scale in vehicle and roadway production, but no longer. Increased driving probably incurs diseconomies of scale in most areas.

Economic efficiency, equity, and long term development are optimized if user prices incorporate total costs. Increasing prices to better reflect costs encourages more efficient use of our transportation system. In the long term this can reduce the need for subsidies to transit and other special programs, due to economies of scale. In the short term, however, increased transit subsidies may be required to overcome decades of under investment. Even with increased use, targeted subsidies may still be justified for modes which serve low income and disabled people for the sake of equity.

Pricing recommendations

Ideally, drivers should pay variable prices exactly equal to all marginal costs. Although it is impossible to create an absolutely "ideal" price structure, a number of practical measures could greatly improve current pricing:

1. Increased fuel taxes are an easy way to internalize some costs, since administrative mechanisms exists, but as discussed in Section 6.1, this is not the best instrument since it does not affect when and where driving occurs. A variety of charges are needed to capture external costs, including weight-mileage changes, congestion fees, pollution taxes, and parking charges. Payments should be frequent so drivers perceive them as marginal costs.

2. Congestion fees can improve traffic efficiency. Several charging methods are available, ranging from highway tolls, to electronic monitoring that automatically charges for mileage and time spent on congested roads. It is important to consider all effects of charges to avoid undesirable consequences. For example, freeway tolls increase congestion on parallel surface roads, and city center tolls can encourage urban sprawl if improperly applied.

3. One of the easiest ways to marginalize costs is to make insurance, registration, licensing, and vehicle taxes proportional to mileage, as discussed in Section 8.3.

4. Another relatively easy and effective strategy for internalizing and marginalizing costs is to require employers to cash out parking subsidies, also discussed in Section 8.3. This means that employees who receive free off-street parking could choose to receive the same value in cash. Parking should be charged daily rather than monthly, so commuters who drive part-time only pay for what they use.

5. As much as possible, commercial parking should also be short term user paid. Parking must be managed at the regional level to prevent communities from using free parking to compete for business, and to prevent spill-over parking problems.

6. Pricing should be used to encourage individuals to buy fuel efficient and low emitting vehicles, and to scrap dangerous, inefficient, and high polluting ones.

9.2 Equity

As discussed in chapters 3.9 and 7, transportation equity is a multi-dimensional problem that depends on individual needs, ability and community circumstances. In automobile dependent communities, anybody who does not have a personal car is disadvantaged. Survey results (described in Section 4.5), transit funding referenda, and handicapped access efforts indicate public support for increased transport equity and diversity.

Underpriced driving cannot be considered equitable. Underpricing forces non-drivers to subsidize automobile use, reduces travel options, and imposes land use and social patterns that increase travel requirements. This would be unfair even if drivers and non-drivers had comparable incomes and abilities (horizontal inequity), and is especially inequitable since non-drivers tend to be economically, physically, and socially disadvantaged (vertical inequity). Efforts to mitigate this inequity by providing direct subsidies for transit service do not eliminate the imbalance between drivers and non-drivers. The relatively low external costs of walking, bicycling, ride sharing, and telecommuting indicate that people who use these modes subsidize SOV drivers.

The equity of increasing motor vehicle user prices depends on how revenue is used. Price increases can be progressive if revenue is used for expenditures that significantly benefit low income people. Using road pricing revenue only for roadway transportation improvements is not necessarily fair or efficient since driving incurs external costs borne by all of society. It is important for both equity and efficiency that society provide affordable and effective travel alternatives before significantly increasing driving costs. These typically include improved public transit service, bicycle and pedestrian facilities, and affordable housing that does not require a car for access to jobs and public services.

Equity recommendations:

More research is needed to define transportation equity, determine ways to measure it, and identify how it is affected by various policies. Many strategies to develop a more efficient transport system also contribute to equity, but some efficiency strategies conflict with equity goals. Here are specific ways to support transportation equity:

7. A basic level of transport should be defined in each community. This might include, for example, freedom to walk safely, access to public services, employment, schools, recreation, and social activities.

8. All transportation policies and programs should be evaluated in terms of how they affect disadvantaged groups.

9. Transportation equity and option value costs should be borne by all of society, not just by users of particular modes. For example, the incremental costs of handicapped access for transit systems should not incorporated into the base price of all transit riders.

10. Transport user price increases should be predictable and gradual to allow individuals to adjust travel patterns (housing and job locations, vehicle purchases, etc.).

11. A significant portion of revenue from increased automobile user charges should be targeted at refunds, tax reductions, and services that benefit disadvantaged people.

12. Transportation equity mitigation should not focus only on transit. Other modes, including walking, bicycling, ride sharing, taxies, delivery services, telecommuting, and land use pattern changes can provide access for non-drivers and the poor.

13. Transition costs associated with reduced automobile dependency and use, such as unemployment in automobile industries, should be anticipated and minimized.

9.3 Land Use Patterns

As discussed in sections 3.14 and 6.4, transportation and land use are interrelated and must be considered together. Low transport prices reduce rent and density gradients. This creates both benefits, which are primarily internalized and capitalized in land values, and costs, which are primarily externalized. Driving contributes to urban sprawl, reduces neighborhood interactions and services, and increases per capita road and parking requirements, causing substantial social and environmental costs.

The impacts of traffic on the public realm and neighborhood environmental quality deserve special attention. The street system (including sidewalks) is the most valuable publicly owned physical asset in most jurisdictions. In addition to accommodating vehicle movement, streets define a community's character, accommodate pedestrian and bicycle travel, and are an important community meeting place. These functions are degraded by automobile traffic. While it is possible to walk, bicycle, and socialize on streets with moderate to high vehicle traffic volumes and speeds, doing so is less efficient, pleasant and safe than on low traffic streets. Subjugating street designs to motor vehicle traffic needs increases automobile dependency and use, exacerbates urban sprawl, and reduces mobility for non-drivers.

Neo-traditional neighborhood design and traffic calming programs described in section 8.6 are increasingly popular strategies to reduce traffic impacts and return streets to multi-function use. Implementing these improvements requires changes in transport planning and funding patterns. Many benefits of increased travel are lost due to competition for location, as discussed in section 6.4. Increased driving ability allows individuals to buy relatively low priced homes at the urban fringe. This perpetuates urban sprawl, increased automobile dependency, and degradation of urban environments. As a result, land prices escalate, more driving occurs, and traffic impacts increase with little or no net benefit.

Land use goals such as greenspace preservation, improved neighborhood environments, and reduced automobile dependency should preempt short term transport objectives. Specific projects and policies should be evaluated in terms of how they support or contradict a community's land use goals. Various land use design factors have been shown to affect automobile dependency and use, including residential and employment density, land use mix, transit service quality, pedestrian and bicycle network quality, and building site design. Effective consideration of these factors can significantly reduce travel demand.

Land Use recommendations:

14. Transportation and land use planning should be integrated so policies and projects are mutually supportive.

15. Prior to developing a transportation plan, communities should establish land use and environmental goals and plans.

16. Transport improvements that contradict land use plans and neighborhood environmental quality goals should be avoided even if they are otherwise justified. In economic evaluation this could be accomplished by assigning "Strategic Goal" cost and benefit factors to factors that support or contradict these goals.

17. Full-cost pricing of land development, utilities and other public services help reduce subsidies that fuel urban sprawl.

18. Parking standards should specify maximum rather than just minimum capacities. Parking requirements should be flexible, and should be reduced where they are not needed due to low automobile ownership (for residential developments) or use (for commercial developments).

19. Zoning laws, development standards, home buyer programs, and other land use and land development policies should be modified as needed to conform with and support community transport goals.

20. Parking management programs are needed to avoid conflicts (such as spill-over parking into residential neighborhoods) and to internalize parking costs.

21. Communities should insure that at least a portion of housing units in all price ranges are accessible to stores, employment, and other public services without driving.

22. Zoning laws and development policies should encourage increased diversity of housing types, infilling and appropriate land use mixing.

23. Greater attention should be paid to streetscape design and development of local activity centers to encourage walking, bicycling and neighborhood interaction.

24. It is especially important to develop moderate density, mixed use communities near rail stations and bus routes.

25. Local services, such as neighborhood stores, local schools, and small parks should be encouraged to reduce travel needs.

26. Zoning and development policies that preserve greenspace and discourage urban sprawl should be implemented.

27. Traffic Calming and other traffic manage- ment strategies should be used to reduce traffic impacts and better accommodate pedestrians and bicyclists on existing

residential and commercial streets. Cities should establish mechanisms to implement traffic management and calming.

9.4 Transportation Decision Making

Transportation decisions have tremendous impacts, many of which tend to be ignored during policy making, planning and budgeting. Planning is often uncoordinated, resulting in a "tyranny of small decisions." Decision makers often treat driving as an end in itself, rather than a means for achieving access, and focus on the benefits of accommodating motor vehicle traffic without assessing total costs. This leads to increase automobile dependency and use, exacerbate environmental and social problems, reduce access for mobility disadvantaged people, reinforce social inequity, and provide less benefit than predicted. Current transport planning practices have five major problems:

- *Limited scope*. Current planning and funding practices do not provide equal consideration to all options for meeting access needs. Demand management tends to be considered and implemented only where traffic congestion or air quality problems are significant, and ignored in other situations. Funding allocation tends to favor roadway improvements over other modes.

- *External costs ignored.* Current planning practices tend to ignore many costs, especially environmental and social impacts. Economic evaluation models can, but usually do not, incorporate monetized estimates of these non-market costs. Even costs such as parking demand and public service demands of increased motor vehicle use are seldom considered in transportation planning and project evaluation.

- *Poor public involvement.* Although transportation decisions impact many aspects of individual and community life, transport planning is considered a technical field and the public is excluded from many critical decisions. Residents are seldom involved early enough in the planning process to place constraints or establish broad goals that reflect community values, and even with citizen involvement transportation decisions are highly influenced by professional biases and preferences.

- *Missing link between transportation and land use planning.* Although transportation and land use patterns are highly interrelated, they are seldom planned together. Transportation planning should be considered a subset of land use and community development planning. Since transport to a large degree determines long term land use patterns, transportation decisions should be based on long term land use goals.

- *Generated traffic effects ignored.* Research described in Section 8.4 shows that increasing road capacity increases total driving, especially in congested areas. As a result, projects that expand urban roadway capacity usually provide significantly less congestion reduction than predicted because latent demand fills much of the new capacity, and automobile use increases throughout the region.

Since most urban trips are relatively short (less than 5 miles), there is a "transportation gap" caused by overemphasis on long-distance travel and too little attention to bicycling, local transit, and low powered vehicles. This creates a self-fulfilling prophecy of increased driving, automobile dependency, inequity and sprawl. Electric cars and other alternative fuels reduce some external costs, particularly urban air pollution, noise, and petroleum externalities, but do not affect others such as accident risk, congestion, and parking subsidies. Introduction of relatively inexpensive, small, low power, low speed vehicles for local travel may offer greater overall savings.

Transportation decision making recommendations:

28. Measures of transport system effectiveness should be based on access rather than traffic volumes and speeds. Policies and programs that reduce the need to travel should be compared equally with measures that increase mobility in planning and funding.

29. Transportation economic analysis must consider all costs. Non-market and indirect costs should be given the same weight as market costs. Non-market costs should be quantified and monetized as much as possible for use in economic evaluation.

30. Least-cost planning should be used as a model for transportation decision making. This means that a broad range of options are considered, including both supply and demand management, and evaluated based on a standard set of criteria that takes into account all costs and benefits. A "no-build" option with land use management strategies should be considered in transport planning and receive equal funding to road building.

31. Research is needed to understand how public policies and land use patterns affect travel decisions, and to develop practical strategies and programs that achieve transportation demand reduction goals.

32. Transport planners should become familiar with the environmental and social impacts of their decisions. Environmentalists, urban planners, and social policy analysts need to learn more about transport issues.

33. Transportation equity and diversity should be recognized as important goals in planning and policy making. Achieving these goals requires development of a diverse and integrated transport system that accommodates non-drivers.

34. Non-motorized transportation modes (walking, bicycling, and telecommuting) deserve increased emphasis in planning and funding. Special attention is needed for intermodal connections, such as the integration of bicycling with transit.

35. Traffic analysis must consider the effects of generated traffic. Generated traffic should be assessed using the "rule-of-half" which recognizes that these trips tend to have relatively low value, since they are trips that users forego if roads are congested.

36. The incremental external costs of generated traffic should be treated as a cost of projects that increase roadway capacity.

37. Many of the resources that are currently targeted at large scale regional transport projects may provide greater benefit if used for local and neighborhood improvements. For example, improvements to local shopping districts, pedestrian and bicycle facilities, and neighborhood services (parks, schools, etc.) may communities to become more self-sufficient and thus reduce motor vehicle traffic and automobile dependence.

38. Transportation professionals and decision makers should make a habit of not using an automobile for at least two consecutive weeks each year in order to experience the practical problems facing non-drivers.

39. Impacts on human life and health, and irreversible environmental damage should be assessed with a low discount rate for the sake of intergenerational equity.

40. Neighborhood car rentals and ownership co-ops should be encouraged to help reduce the need for residents to own cars and trucks that are seldom used to capacity.

9.5 Research Recommendations

Further research is needed on transportation external costs including air pollution, noise, accident expenses, parking subsidies, and municipal service costs to give representative values for different communities and driving conditions. For example, several estimates of air pollution exist, but most are either for areas with extreme pollution problems, such as Southern California, or they are nationwide totals.

Transport equity and diversity appear to be significant values and which deserve much more research. The concept of automobile dependency deserves more analysis. Research is needed to identify factors that contribute toward automobile dependency, ways to quantify its costs, and strategies for reducing it.

Transportation land use impacts need more research to understanding of how transport decisions affect land use, and methods to measure and monetize these effects. This research should cover impacts to both natural environments, such as the loss of wildlife habitat and landscapes, and impacts on the built environment, such as the degradation of neighborhood life from high traffic volumes. These appear to be significant costs with major implications to many transport decisions.

The barrier effect (severance) has been well studied and measured in Scandinavian countries, but their quantification techniques have not been applied in North America. Research is needed to test the Scandinavian formulas here and develop estimates of this cost per vehicle mile under a variety of typical conditions.

Latent demand has tremendous implications on transport decisions. Some progress has been made to develop tools for predicting generated traffic. We need more information to help predict generated traffic on highly congested roads and other typical conditions. Most current studies focus on traffic generated on single roads. Of equal or greater importance is the overall increase in regional automobile use that results from increased road capacity.

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