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16. Abstract

This report addresses a primary dilemma of the transportation planning community, namely, how to evaluate and compare urban passenger transportation projects regardless of mode. After identifying the full-cost approach as an effective tool for undertaking such comparisons, this report describes MODECOST, a full-cost evaluation model developed by the Center for Transportation Research (CTR) of The University of Texas at Austin. Although many of the issues that MODECOST addresses have been considered previously during the transportation investment decision process, MODECOST quantifies the costs inherent to each issue.

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Research Report Number 1356-1

Research Project 0-1356
Development of an Urban Transportation Investment Model

conducted for the

Texas Department of Transportation

in cooperation with the

U.S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH
Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

September 1996

IMPLEMENTATION RECOMMENDATIONS

Given its effectiveness for valuing transportation investment alternative comparisons, full-cost analysis represents a critical element in multimodal transportation investment planning. In terms of implementation, the findings in this report suggest that the full-cost analysis — using the MODECOST evaluation model — is capable of enhancing qualitative assessments and planning/engineering judgment.

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

DISCLAIMERS

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation.

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SUMMARY

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CHAPTER 1. INTRODUCTION

1.1 THE PRESENT CONTEXT FOR URBAN PASSENGER TRANSPORTATION INVESTMENT DECISIONS

Traditionally, transportation decision makers have compared highway projects among highway projects and transit projects among transit projects; consequently, for the most part, the two types of transportation projects (including such others as bicycle and pedestrian projects) are never compared with each other. This approach arose from two somewhat related factors. First, the past four decades of federal funding for highways underscored the idea that they were necessary to the nation's security and economic health. This meant that transportation planning aimed at resolving community transportation needs was biased toward roadway and personal vehicle solutions.

The second reason that highway and transit projects are rarely considered collectively is the lack of an appropriate methodology for such an evaluation. That is, the methods of evaluating highway projects rely on measures of level-of-service (LOS) improvement, the number of accidents that an improvement might prevent, and on the savings that will ultimately accrue to the users of the highway. By contrast, transit projects are evaluated in terms of increases in transit ridership and of travel time savings for users.[1] Because these measures of effectiveness are applicable to each mode uniquely, and not to all modes universally, they do not lend themselves to holistic planning.

Recently, however, there have been positive moves toward developing a methodology for comparing the different modes — a move prompted primarily by budget concerns. Both federal and local transportation funding sources are failing to keep up with needs, necessitating more and better information be provided to community leaders charged with making difficult decisions. Although the federal commitment to a national highway system continues, the fact is that needs (especially with regard to maintenance) are quickly outpacing funding sources. Whether because other funding choices have had higher priority; whether because of complacency on the part of leaders who don't remember a time prior to the implementation of the Interstate system (or who judge it to be sufficient in its current configuration); or whether because leaders are more concerned with the now enormous task of maintaining and revitalizing the existing system — whatever the reasons, this situation has challenged federal, state, and local agencies to seek out alternative sources of financing, as well as strategies for choosing the most cost-efficient projects. Clearly, the passing of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991 signaled a growing awareness by federal legislators of the importance of roadway alternatives in solving transportation problems.

Yet while policy and planning have sought to better compare alternative transportation modes, the average transportation consumer shows increasingly less inclination to use these alternative modes. For instance, according to the Nationwide Personal Transportation Survey, vehicle-miles traveled between 1983 and 1990 increased over 40 percent. Almost 17 percent of this

[1] DeCorla-Souza, P., and R. Jensen-Fisher. "Comparing Multimodal Alternatives in Major Travel Corridors," *Transportation Research Record 1429* (Transportation Research Board), 1994.

increase is attributable to a shift from shared vehicle and non-motorized vehicle modes to personally operated vehicles, which accounted for 82 percent of all travel in 1983 and 87 percent in 1990.[1] The same study attributes the rest of the increase in vehicle-miles traveled to increased person trips per capita, increased vehicle trip length, population increase, and to a decrease in average vehicle occupancy. These trends indicate that the private vehicle is increasingly the mode most often chosen.

This present U.S. situation differs substantially from that in Europe. As shown in Figure 1.1, private motor vehicles accounted for only 48 percent of the urban passenger trips in Germany, 47 percent in France, 45 percent in England, and 42 percent in Denmark. Without a doubt, U.S. passenger travel is dependent on highway infrastructure serving private vehicle needs. As shown in Figure 1.2, of the $796 billion of U.S. transportation expenditures in 1990, 83 percent went to highway surface transportation.

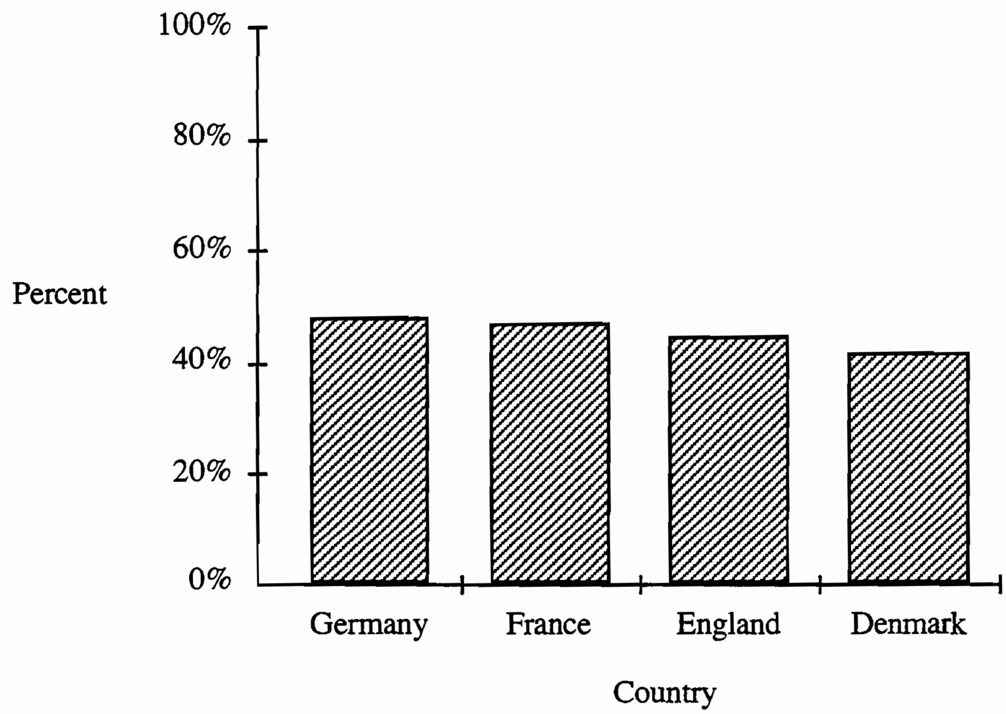

Figure 1.1 Percentage of Urban Trips by Private Vehicle

Source: MacKenzie, J. J., R. C. Dower, and D. D. T. Chen. *The Going Rate: What It Really Costs to Drive*, World Resource Institute, 1992.

[1]Pisarski, A. E. *Nationwide Personal Transportation Survey, Travel Behavior Issues in the 90's* (Office of Highway Information Management, HPM-40, U.S. Department of Transportation, Federal Highway Administration), July 1992, pp. 11-14.

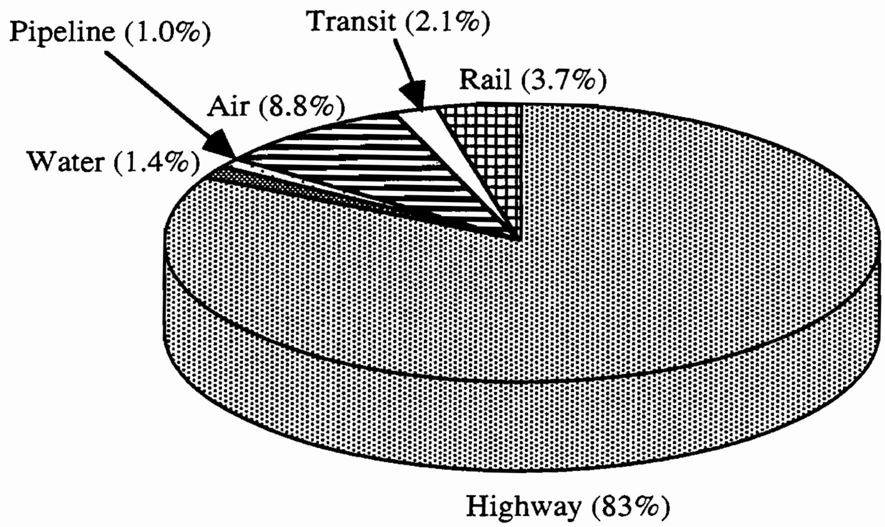

Figure 1.2 Distribution of 1990 U.S. Transportation Expenditures

Source: Volpe National Transportation Systems Center. *National Transportation Statistics: Annual Report 1992*, Government Printing Office, U.S. Department of Transportation, Washington, D.C., 1992.

For U.S. policy makers and planners, the traveling public's reliance on the private motor vehicle seemingly begs a number of questions: Do individuals naturally prefer the private vehicle, or has the planning and funding bias toward the private vehicle subsidized that mode to the detriment of other modes? And, whether or not people prefer one particular mode, if that mode is more costly to society as a whole, can society continue to subsidize it?

1.2 PROBLEM STATEMENT

This report addresses a primary dilemma of the transportation planning community — how to evaluate and compare urban passenger transportation projects regardless of mode and to the maximum benefit to the community. Chapter 2 documents this need, forwards the full-cost approach as a likely candidate, and reviews the literature addressing this topic. In Chapter 3, the MODECOST model developed by the Center for Transportation Research (CTR) of The University of Texas at Austin is introduced and described. Chapter 4 demonstrates the application of MODECOST to a corridor in San Angelo, a midsize Texas community.

The MODECOST model was developed by CTR under a research study sponsored by the Texas Department of Transportation. The study, entitled "Development of an Urban Transportation Investment Model," is scheduled to deliver (1) a report on full-cost decision-making, (2) the MODECOST software developed by CTR to perform full-cost analysis, (3) a technical report on MODECOST, and (4) several case-study reports describing the application of MODECOST to specific corridors in Texas.

The case studies are intended to demonstrate the applicability of MODECOST specifically and full-cost models in general for comparing urban passenger transportation investments.

Although many of the issues that MODECOST addresses have been considered previously during the transportation investment decision process, MODECOST quantifies the costs inherent to each issue.

CHAPTER 2. EMERGENCE OF FULL-COST ANALYSIS AS A PLANNING TOOL

2.1 THE FUNDING CRUNCH AS AN IMPETUS TO CHANGE

Perhaps the most urgent call for change in transportation decision making has come in response to the looming (some would say present) transportation funding crisis, which is affecting both new construction and the maintenance of existing structures. This crunch is being felt at all governmental levels.

For example, regarding the state's transportation finance situation, the 1994 Texas Transportation Plan has identified a serious deficit between projected funds and projected needs between 1995 and 2014 for highways and non-metropolitan bus transit and intercity bus transit modes. Metropolitan Transit Authorities, which operate in Austin, Corpus Christi, Dallas, El Paso, Fort Worth, Houston, and San Antonio, will "likely be able" to operate and make most of their necessary capital investments because they can levy sales taxes.[1] The figures, divided between highway/bridge projects, as shown in Table 2.1, and transit needs, as shown in Table 2.2, are based on existing revenue sources projected into the future. For both groups, the projected revenue over the span of the plan equals a mere 40 percent of projected need.

It is this concern that has prompted state departments of transportation all over the nation to look toward new and different methodologies for evaluating projects. That is, with the scarcity of funding, deciding which projects to fund becomes more difficult and carries with it greater responsibility to taxpayers than ever before. Local and metropolitan planning organizations are in similar financial straits.

Table 2.1 Highways and Bridges: Full Needs Scenario[2]

(costs in $ millions)

Need and Funding Category	Plan Period by Quartiles				Total
	1995-1999	2000-2004	2005-2009	2010-2014	1995-2014
Total Highway and Bridge Needs	$23,025	$31,666	$37,760	$41,795	$134,246
Projected Available Funding	$14,169	$12,967	$13,267	$13,324	$53,727
Projected Deficiency	$8,856	$18,699	$24,493	$28,471	$80,519
Funding as a % of Need	62%	41%	35%	32%	40%

[1]Dye Management Group, Inc. *The Texas Transportation Plan* (Texas Department of Transportation), 1994, p. 70.
[2]Dye Management Group, Inc. *The Texas Transportation Plan* (Texas Department of Transportation), 1994, p. 65.

Table 2.2 Projected Needs and Funding: Elderly and Disabled, Rural and Non-urban, and Small Municipal Transit[1]

(costs in $ thousands)

Transit System	Plan Period by Quartiles				Total
	1995-1999	2000-2004	2005-2009	2010-2014	1995-2014
Elderly and Disabled Transit Needs	$36,007	$39,608	$43,568	$47,925	$167,108
Rural and Non-urbanized Transit Needs	$218,009	$239,810	$263,791	$290,170	$1,011,780
Small Municipal Transit Needs	$196,404	$216,044	$237,649	$261,414	$911,511
Total Transit Needs	$450,420	$495,462	$545,008	$599,509	$2,090,399
Projected Transit Revenues	$274,217	$184,300	$184,300	$184,300	$827,117
Projected Deficit	$176,203	$311,162	$360,708	$415,209	$1,263,282
Funding as a % of Needs	61%	37%	34%	31%	40%

2.2 TRANSPORTATION PLANNING POLICY CHANGES

In the U.S., the impact of the federal government on urban transportation planning has been greater than that of state and local governments. The federal government sets policy, and compliance with policy tends to be encouraged through funding mechanisms. That is, the distribution of transportation funds from the federal government to state and local jurisdictions is structured so that funds are specified for certain types of projects by categories — e.g., Interstate construction, Interstate maintenance, safety, traffic management, railroad, and bridge. Given this influence, much of the need to explore new methods to evaluate transportation alternatives has arisen from changing federal policies with regard to transportation.

While transportation legislation and policy have slowly been evolving toward a more integrated modal approach over the past few decades anyway, concerns about the environmental impact of transportation and energy conservation concerns have played a role in facilitating this evolution. In general, state initiatives will echo national initiatives; thus, the recent Texas Transportation Plan notes the importance of changing transportation decision making strategies.

2.2.1 The Intermodal Surface Transportation Efficiency Act of 1991

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) is the current federal law relating to the nation's transportation system; it is a carrot whose attraction is a substantial number of federal dollars allotted to transportation.

The ISTEA legislation, though it was in some ways built upon previous transportation law, represents a decided step away from traditional transportation decision making. Four decades

[1]Dye Management Group, Inc. *The Texas Transportation Plan* (Texas Department of Transportation), 1994, p. 70.

earlier, President Eisenhower signed the Highway Act of 1956, providing for the construction of the Interstate Highway System and effectively starting the "Era of Highways" in the United States. Other subsequent legislation and policies continued to reward the creation and maintenance of highways and reinforced dependence on the automobile. ISTEA is a product of that history, but it differs in that it has also given some teeth to some new ideas.

The "new" ideas in ISTEA — intermodalism and efficiency — are only relatively new. Intermodalism was mentioned as early as the Federal-Aid Highway Act of 1962:

> It is declared to be in the national interest to encourage and promote the development of transportation systems embracing various modes of transport in a manner that will serve the states and local communities efficiently and effectively.[1]

By 1991, the wording, as appearing in ISTEA, had not changed substantially:

> It is the policy of the United States to develop a National Intermodal Transportation System that is economically efficient and environmentally sound, provides the foundation for the Nation to compete in the global economy, and will move people and goods in an energy efficient manner.[2]

It was ISTEA, however, that moved the U.S. closer to the incorporation of intermodalism in the transportation planning process. ISTEA followed previous legislation in allotting funds for both highways and mass transit in the same act. It authorized $151 billion over six years for highways, mass transit, and safety programs. The Interstate System brought into being in the 1950s was retained, though now incorporated into the larger National Highway System.

Significantly, ISTEA created the Surface Transportation Program (STP), a block grant program that accounts for $23.9 billion over six years at an 80 percent matching federal share. The program provided the potential for funding non-traditional as well as traditional highway-related projects. Funds for the program can be used for highway construction; transit capital projects; carpool, parking, bicycle, and pedestrian facilities; safety improvements for highways and mass transit; traffic monitoring, management, and control; transportation control measures; as well as wetland mitigation efforts.[3] As alluded to earlier, federal apportionments are categorized so that state and local jurisdictions must use the funding as Congress intended. For example, Texas received approximately $30 million in 1994 earmarked for the Surface Transportation Enhancement Program. Under this program, communities, non-profits, and public agencies across the state competed for funding for such projects as renovating historic railroad depots, building hike/bike

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[1]Weiner, E. *Urban Transportation Planning in the United States: An Historical Overview,* DOT-T-93-02 (Office of the Secretary of Transportation, in cooperation with the Technology Sharing Program, U.S. Department of Transportation), November 1992, p. 42.

[2]Weiner, E. *Urban Transportation Planning in the United States: An Historical Overview,* DOT-T-93-02 (Office of the Secretary of Transportation, in cooperation with the Technology Sharing Program, U.S. Department of Transportation), November 1992, p. 243.

[3] Weiner, E. *Urban Transportation Planning in the United States: An Historical Overview,* DOT-T-93-02 (Office of the Secretary of Transportation, in cooperation with the Technology Sharing Program, U.S. Department of Transportation), November 1992, p. 244.

trails, and beautifying highway landscapes. This type of program, not featured in previous transportation funding bills, was mandated by Congress and implemented by the states because the funding mechanisms earmarked the money for that purpose alone. The widened menu of transportation options, of which the Enhancement program is a part, provides greater flexibility in solving transportation problems, yet represents a challenge to decision makers who must compare the relative benefits of such varied strategies.

The intermodal aspect of ISTEA lies not only in its emphasis on increased funding for alternative modes, but also in the acknowledgment that these modes can contribute to a national transportation system. The act does not provide much direction with regard to the "inter," or connecting, aspect of the different modes, except to establish state and national advisory boards on the subject. As a 1992 General Accounting Office study found, general multimodal planning was rare; the report recommended the development of multimodal criteria and evaluative tools.[1]

ISTEA addresses many other issues, including bridge replacement and rehabilitation, a Congestion Mitigation and Air Quality (CMAQ) Improvement Program to coordinate with the 1990 Clean Air Act Amendments, state funding equity, tolls, and trails. Clearly, the focus of transportation funding has broadened considerably since the Federal Highway-Aid Act of 1956. In addition to addressing intermodalism, ISTEA reflects a national concern with efficiency — conserving energy, making existing facilities more efficient and longer lasting, and minimizing societal costs.

Energy conservation concerns first gained widespread attention in 1973, with the Organization of Petroleum Exporting Countries' (OPEC) embargo. The 1979 oil crisis intensified the concern, making national energy conservation an issue of economic health and security. Because transportation is a sector that consumes significant energy, improvements in transportation energy consumption can significantly impact statewide and national figures. By widening the scope of possibilities for federal funding, and by mandating the consideration of such factors as consistency with applicable federal, state, and local energy conservation programs, ISTEA promotes energy conservation ideals.

And yet fuel conservation is only one facet of the efficiency standards that ISTEA encourages in the decision-making process. For instance, also among the 16 planning factors which ISTEA mandates, existing transportation facilities should be preserved and used more efficiently when possible, the effects of all transportation projects in the area should be taken into account, as should the overall social, economic, energy, and environmental effects of transportation decisions. For example, ISTEA specifically earmarks funding for maintenance and preventative maintenance, rehabilitation, and, for areas in nonattainment status for air quality, funding for non-capacity-added congestion mitigation projects.[2] In a larger perspective, ISTEA also encourages efficiency by stressing the importance of linkages between modes. The theory behind intermodalism is that the entire system will operate more efficiently if passengers and freight shipments can easily transfer between modes, and if there is a variety of modes from which to choose.

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[1] *Transportation Structure: Urban Planning Can Better Address Modal Trade-Offs* (General Accounting Office, GAO/RCED-92-112), April 1992.

[2] *1996 Project Development Plan, Exhibit A* (Texas Department of Transportation), October 26, 1995.

This issue of efficiency, both in energy conservation and societal cost terms, along with the enunciation of an intermodal vision for the nation's transportation network, is at the heart of ISTEA and the latest innovations in transportation planning. Among the checks on transportation alternative expansion, however, are the Clean Air Act Amendments of 1990. This legislation seeks to ensure that one of the more important, but less easily measured, costs of transportation — the environment — is not sacrificed. These amendments are described below.

2.2.2 The Clean Air Act Amendments of 1990

Alongside the transportation planning reforms introduced by ISTEA are the control reforms introduced by the Clean Air Act Amendments (CAAA) of 1990. The CAAA works in tandem with ISTEA to ensure that transportation improvements do not degrade air quality unncessarily.

One of the fundamental changes in the 1990 CAAA regards the requirement that state transportation plans conform to state air plans. (State air plans are also known as State Implementation Plans, or SIPs.) The purpose of the state air plan is to eliminate and reduce air quality violations. Previous legislation had required that the state transportation plan conform to the state air plan, but the provision was never interpreted to mean that the transportation plan as a whole conform, merely that the air plan transportation control measures be listed in the transportation plan as well. By 1990, that provision had been tightened to prohibit the expenditure of any funds on projects in a transportation plan or program unless the plan and program conform in their entirety to the state air plan. This change in transportation planning policy recognized that air quality programs had to be implemented on a regional and statewide scale in order to be effective.

The CAAA also addresses mobile source emissions through new requirements for ozone control plans. Mobile sources — cars, buses, and trucks — produce carbon monoxide, nitrogen oxides, and volatile organic compounds, the latter two of which contribute to ground-level ozone and related air pollution. Transportation plans that reduce traffic congestion and the number of vehicle-miles traveled also reduce these air pollutants.

When an area fails to meet national ambient air quality standards (NAAQS), it is labeled a "nonattainment area." Texas is one of ten states that has been classified by the U.S. Environmental Protection Agency as having "severe" nonattainment areas. Nonattainment areas are required to develop air quality plans and take steps to reduce these pollutants. In cases of noncompliance with these air quality requirements, ISTEA and the CAAA can freeze federal transportation funds (except those needed for safety or air quality programs). Whereas ISTEA in many ways acts as a carrot toward implementing intermodal and efficient modes of transport (many of which act to improve air quality), the Clean Air Act Amendments of 1990 are the complementary "stick" that provides a reason for that greater efficiency and intermodalism.

2.2.3 A State Perspective: The Texas Transportation Plan

The Texas Transportation Plan reflects the national agenda for better transportation alternatives and compliance with clean air requirements. The recently completed 1994 edition of the Texas Transportation Plan notes that the existing funding structure for transportation will not meet the state's needs, and that the mechanisms themselves do not always lead to efficiency and effectiveness. Elaborating further, the plan states that "this is because users often do not pay for the full-costs they impose on the system, and because current funding mechanisms are not flexible enough to allow for the best use of scarce resources."[1] The plan also notes special requirements for which the state's finances are not sufficient: needs resulting from the recent passage of the North American Free Trade Agreement, a project backlog, very large projects necessitated by economic growth, and special concerns of major cities.

Policies 22 and 26 of the state plan have particular relevance for transportation decision making. Policy 22 calls for the optimization of the use of existing funding sources. Strategy 22.1, "Focus on projects with the greatest return on investment," enunciates two potential actions, as follows:

Potential Action 22.1.1	Use benefit-cost analysis in evaluating projects to be included in the Statewide Transportation Improvement Program to ensure the greatest return on investment.
Potential Action 22.1.2	Use life-cycle costing in developing project cost estimates and in evaluating projects for the Statewide Transportation Improvement Program to ensure consideration of all costs.

In a similar vein, Policy 26 calls for a transportation revenue structure that ensures cost responsibility. Strategy 26.1, "Internalize the true costs of the transportation decisions of all users to the extent possible," suggests three potential actions.

Potential Action 26.1.1	Analyze existing user fees to change the structure towards greater cost responsibility.
Potential Action 26.1.2	Implement a weight-distance tax or increase vehicle registration fees for commercial trucks to achieve greater cost responsibility.
Potential Action 26.1.3	Evaluate congestion pricing, emissions fees and similar measures to provide greater cost responsibility for the environmental and congestion-related effects of automobile use.

Policy changes in Texas with regard to transportation are not taken lightly, as the hesitant wording of "potential actions" indicates. Nonetheless, the elaboration of these strategies and potential actions in the Texas Transportation Plan indicates an increasing awareness by decision makers and transportation agencies that the current method of evaluating transportation alternatives is unable to meet current and future system needs. It is within this context of federal and state policy shifts that full-cost modeling has emerged as a decision-making tool.

2.3 FULL-COST ANALYSIS

In this context of funding dilemmas and intermodalism, full-cost analysis has arisen as a methodology that improves transportation decision making. This section of the report reviews several works that have addressed full-cost and related analyses and discusses general issues that have been raised concerning the approach. The following works, presented chronologically,

[1] Dye Management Group, Inc. *The Texas Transportation Plan* (Texas Department of Transportation), 1994, p. 48.

include those that call for intermodal alternative comparisons, models that employ other economic evaluation tools (e.g., benefit-cost analysis), as well as full-cost models.

2.3.1 An Early Benefit-Cost Analysis for Highways

By the end of the 1940s, the U.S. Bureau of Public Roads and the American Association of State Highway Officials (AASHO) Committee on Planning and Design Policies were working on the development of analysis methodologies which would be generally applicable for highway projects. In 1952, the Association published an informational report, *Road User Benefit Analyses for Highway Improvements*, and a companion manual, the two of which formed the basis for benefit-cost analysis for highway projects.

The basic tenet of the above manual was the concept that "a profit should be returned on an investment applies as well to highway projects as to general business ventures."[1] According to this manual, the benefit was equal to the difference between alternate routes in road user costs including fuel, other operating costs, comfort and convenience, vehicle ownership costs, and safety. The value of time was equal to $1.35 per vehicle hour ($0.75 per person hour); the value of comfort and convenience varied according to the type of road (0 cents per mile for the best conditions and 1.0 cents per mile for the worst).[2] To get the benefit-cost ratio, this benefit figure was divided by the difference in construction costs between the alternate routes. This manual represented a positive step toward economic analysis as a decision-making tool in transportation planning, but the tool was intended for comparison of alternatives within the highway mode alone.

2.3.2 The Full-Costs of Urban Transport, Part III: Automobile Costs and Final Intermodal Comparisons (1975)[3]

This study developed cost estimates and performed comparisons for auto, bus, and rail modes using data for the San Francisco Bay area. Beyond merely incorporating operating and maintenance costs, this project also looked at time and pollution costs.

This study discussed the importance of using time value in the cost comparison. For instance, time value functions as a measurement of the convenience of a mode, especially private vehicle travel. Minimizing this cost, however, entails increasing the operating cost per passenger. For example, increasing the number of buses to decrease the time spent waiting for one entails increasing the cost of providing those buses, and hence the operating cost per rider. Similarly, for the auto, minimizing the cost of the time spent on highways translates into lower volume-to-capacity ratios on roadways, perhaps through increased capacity, which is again a greater cost per driver. The author is correct in asserting that the value of time is a necessary measurement of a

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[1] A Basis for Estimating Traffic Diversion to New Highway in Urban Areas, American Association of State Highway Officials 38th Annual Meeting, Kansas City, Kansas, December 1992, cited in Weiner, E. *Urban Transportation Planning in the United States: An Historical Overview,* DOT-T-93-02 (Office of the Secretary of Transportation, in cooperation with the Technology Sharing Program, U.S. Department of Transportation), November 1992, p. 27.

[2] Weiner, E. *Urban Transportation Planning in the United States: An Historical Overview,* DOT-T-93-02 (Office of the Secretary of Transportation, in cooperation with the Technology Sharing Program, U.S. Department of Transportation), November 1992, p. 28.

[3] Keeler, T.E., and K.A. Small. *The Full Costs of Urban Transport, Part III: Automobile Costs and Final Intermodal Comparisons* (Institute of Urban and Regional Development, University of California, Berkeley), 1975.

mode's convenience (and therefore a person's propensity to use it, as well), yet it does introduce more complexity into any model.

Summarizing the study, Keeler noted that the bus is consistently more efficient than auto transport (average 1.5 passengers per auto) for all interest rates, time values, and trip lengths, where traffic density is greater than 5,000 passengers per peak hour.[1] Another pattern is that bus is less costly than rail at every traffic density studied.[2] And third, even a private automobile (subcompact, average auto occupancy of 1.5) is cheaper than rail transport for passenger densities up to 20,000 per hour.[3] According to his results, Keeler asserted in 1975 that, unless people enjoyed riding a train considerably more than riding a bus (and this is an argument that is heard increasingly today with regard to light rail, so this may be the case), and holding fare, travel time, and all other things equal, building a fixed transit line in the Bay Area could not be justified. Of course, BART was ultimately built despite Keeler's findings.

2.3.3 Royal Commission on National Passenger Transportation

In their study of Canada's system, the Royal Commission on National Passenger Transportation[7] recommended that transportation policies be guided by four objectives; safety; environmental protection; fairness to tax payers, travelers and carriers; and efficiency, so that services are provided only where the benefits to the individual traveler equal or exceed the cost, and given levels of service are provided at the lowest possible cost. The study discusses the significance of efficiency overall and proposes a marginal-cost pricing strategy to achieve that objective. These arguments are important to the theoretical foundation of this project and so merit further elaboration here.

According to the authors, efficiency serves as the backbone of all four transportation objectives. Efficiency implies that society will spend no more on capital facilities than it should, nor employ more people than necessary; that government will no longer spend money on a particular transportation service, despite more worthwhile alternatives; and that decision makers will not fail to account for long-term maintenance costs in choosing a particular project. Protecting the environment, maintaining safety, and fairness can be achieved at adequate levels by including the efficiency objective.

In order to achieve the four objectives, and in particular to maintain an efficient transportation system into the future, the Royal Commission recommends that each traveler pay the full cost of his or her travel, and that travelers, in total, pay the full cost of the passenger transportation system, including those costs related to protecting the environment, safety and accidents. Currently, taxpayers support the transportation system knowingly through direct subsidies and unknowingly through hidden subsidies. Direct subsidies are those that governments

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[1]Keeler, T.E., and K.A. Small. *The Full Costs of Urban Transport, Part III: Automobile Costs and Final Intermodal Comparisons* (Institute of Urban and Regional Development, University of California, Berkeley), 1975, p. viii.

[2]Keeler, T.E., and K.A. Small. *The Full Costs of Urban Transport, Part III: Automobile Costs and Final Intermodal Comparisons* (Institute of Urban and Regional Development, University of California, Berkeley), 1975, p. viii.

[3]Keeler, T.E., and K.A. Small. *The Full Costs of Urban Transport, Part III: Automobile Costs and Final Intermodal Comparisons* (Institute of Urban and Regional Development, University of California, Berkeley), 1975, p. ix.

show in their budgets as amounts transferred to carriers or travelers from the taxpayers. These include fuel taxes, property taxes, and registration fees. Hidden subsidies are those that are less visible to the public, such as the cost of damage to the environment. At present, governments allow transportation activities to cause damage to the environment without charging carriers or travelers for these damages. This is equivalent to a subsidy from the public, both present and future generations, who experience the adverse effects on the environment. The Royal Commission argues that the four objectives "will be best achieved if the passenger transportation system is supported and maintained by those who use it. Travelers should pay for the travel services they use. People who do not travel should not have to pay for those who do." And, indeed, the authors do suggest a marginal-cost pricing strategy for exacting these costs from travelers.

Having presented these four objectives and how best to achieve them, the Royal Commission continues by proposing a marginal-cost pricing strategy to recover the full cost of transportation. Marginal cost is not a new concept. In fact, the earliest efforts of marginal cost can be traced to the work of Ellet and Dupuit.[1] In the early twentieth century, pioneer work by Pigou[2] set the basic analytical framework, which was later modeled formally in a short-run framework by Walters.[3] Morhing and Harwitz [4] extended the analysis into a long-run framework and established the relationship between optimal tolls and optimal long-run utilization of the road network. Additional refinements and extensions have been made by economists Johnson[5], Mohring[6], Vickery[7], and Dewees.[8]

Marginal cost is defined as the additional cost that results from a small increase in the amount provided of a product or service. For example, the marginal cost of a road is the cost of the wear on the road incurred each time a vehicle uses the road. In general, if users do not have to pay for this marginal cost, they may choose to make an unnecessary trip, or use a vehicle that is cheaper to operate but causes more road wear. The benefits of such trips to the user are small, but the costs to the taxpayer may be substantial.

Despite the support of the Canadian study for a marginal cost approach, it has several limitations in application. First of all, marginal cost is difficult to measure and varies by circumstance. For example, the marginal cost of congestion during peak periods differs from that for off-peak hours. Second, it is very difficult to charge the users marginal cost even if it can be

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[1]Ellet, C. *A Popular Exposition of the Incorrectness of the Tariffs on Tolls in Use on the Public Improvement of the United States,* J. Franklin Institute, 1840. Dupuit, J., *On the Measurement of the Utility of Public Works*, reprinted in Transport. Ed.: D. Munby. London, England, [1844] 1968. As cited by C. Winston in "Conceptual Developments in the Economics of Transportation: An Interpretive Survey," *Journal of Economic Literature,* Vol XXIII, 1985.

[2]Pigou, A. C. *Wealth and Welfare,* MacMillan: London, 1912.

[3]Walters, A. A. "The Theory and Measurement of Private and Social Cost of Highway Congestion," *Econometrica*, 29, 1961.

[4]Mohring, H., and M. Harwitz. *Highway Benefits: An Analytical Framework*, Northwestern University Press, IL, 1962.

[5]Johnson, M. B. "On the Economics of Road Congestion," *Econometrica, 32*, 1964.

[6]Mohring, H. "Urban Highway Investments," *Measuring Benefits of Government Investments*, The Brookings Institute, 1965.

[7]Vickery, W. "Congestion Theory and Transport Investment," *Amer. Econ. Rev.*, 59, 1969.

[8]Dewees, D. "Estimating the Time Costs of Highway Congestion," *Econometrica*, 47, 1979.

computed. Third, since marginal cost is associated with additional users, it may cause deficits. For example, a facility serving 10 users costs \$100 per day, for an average cost of \$10 per user. With each additional service at \$5 per user, it costs \$150 to serve 20 users. If the price for all users is set at the marginal cost, \$5 per user, revenue would be only \$100, resulting in a deficit of \$50. These weaknesses have inspired several different corrective strategies, as discussed below.

To avoid a deficit, prices may be set equal to average costs. This approach, however, is not as simple as it appears. One consideration is that for different categories of vehicles, the marginal costs of roadway damage are different. Another is that the marginal costs of congestion for different time periods are different. Another corrective strategy, charging more than the marginal cost, is also inefficient because some potential users who would have been willing to pay the marginal cost and who would have gained from using the facility, will not do so at the higher price, resulting in a loss to the economy. And yet the strategy of setting the price equal to the marginal cost means general taxpayers would be financing the deficit and would in effect be paying for a part of the provision of benefits to users. Taking all of the above into consideration, users have to pay the full cost of the transportation system they use, assuming that such costs are no higher than necessary; as just explained in many cases a policy of full cost recovery may necessitate that prices be set above marginal cost.

The Canadian study makes one more observation regarding marginal cost pricing strategy. In making investment decisions to add or close transportation facilities, it is necessary to determine how much users value the basic facilities, not just how much they value additional amounts of service or use. Marginal cost pricing thus does not provide a complete test for the value of transportation to users. The following section discusses a newer approach.

2.3.4 The Price of Mobility: Uncovering the Hidden Costs of Transportation (1993)[1]

In their study, Miller and Moffet address the issue of cost and valuation with regard to transportation. The modes they address include cars, buses, and trains. They summarize literature on the topic and present a methodology for estimating costs based upon national aggregate data. The cost estimations they provide are presented both in total national cost and average cost per passenger-mile-traveled. The orientation of the study leans toward a national perspective on the costs of transportation.

Of the authors' principal conclusions, of particular interest is their calculation of the estimated average cost per passenger mile of each of the three modes under consideration. They note that the cost per passenger mile traveled for autos is 38 to 53 cents, for buses 35 to 40 cents, and for rail 48 to 52 cents. These cost estimates, as Miller and Moffet themselves point out, are not definitive.

The authors deliberately note that they consider their cost estimations to represent only one side of a benefit/cost evaluation. That is, although they calculate costs for each mode, they state that comparison of modes must include consideration of the benefits of each mode, which was outside the scope of their study. The approach of the report is to address costs for each mode in the following cost categories:

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[1]Miller, P., and J. Moffet. *The Price of Mobility: Uncovering the Hidden Costs of Transportation* (Natural Resources Defense Council), October 1993.

Personal costs	Air pollution
Capital and operating costs	Water pollution
Local services	Wetlands
Energy	Land loss
Congestion	Urban sprawl
Parking	Property values
Accidents	Transportation Equity
Noise	Historic buildings and archeological properties
Building vibration damage	

Many of these categories are self-evident, some less-so because they are less often included in cost computations. Local services is one such example. All levels of government contribute to this cost category, which includes traffic control, parking enforcement, policing theft, public education, disposal of auto byproducts, and drainage systems to serve facilities. With regard to the Energy category, as well, Miller and Moffet include some costs that do not appear on most transportation project decision matrices. For example, their calculation for this cost includes a portion of federal subsidies received by the oil industry each year, as well as an estimated cost of diminishing energy security and balance of trade problems which the researchers link to oil dependence.

Miller and Moffet discuss the calculation of the costs of congestion at some length. Owing to the complexity of the issue, they examined three different approaches to estimate congestion costs. One method measures the costs that would have to be imposed upon users in order to reduce the congestion to an acceptable level.[1] As Miller and Moffet point out, a limitation of this approach is the variation of users' costs by geographic location and time of day. A second approach relates the cost of the excess traffic to the cost of providing facilities to accommodate it.[2] A third approach, the one which appears to form the basis for their final estimate, is to quantify delay based upon an estimated dollar value of travel time.[3] The authors indicate that they would like to also include the cost of stress to travelers in their estimate, but cite a lack of research data on which to base such a figure. Other costs of congestion, for example fuel expense and higher insurance premiums, are included in other categories. Notably, congestion costs are not estimated for buses or rail.

Miller and Moffet's study supports the general observation that all three modes — auto, bus, and rail — are each heavily subsidized. The distinction lies in the type of subsidy received.

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[1]Lee, D.B. "Net Benefits From Efficient Highway User Charges," *Transportation Research Record 858*: 14-20 as cited in Miller, P., and J. Moffet. *The Price of Mobility: Uncovering the Hidden Costs of Transportation* (Natural Resources Defense Council), October 1993.

[2]*Roadway Congestion in Major Urbanized Areas 1982 to 1988*, FHWA Research Report 1131-3 (Texas Transportation Institute, College Station, Texas) 1990, and Litman, T. *Transportation Efficiency, An Economic Analysis* (unpublished draft thesis, Evergreen College, Washington) 1991, as cited in Miller, P., and J. Moffet. *The Price of Mobility: Uncovering the Hidden Costs of Transportation* (Natural Resources Defense Council), October 1993.

[3]*Roadway Congestion in Major Urbanized Areas 1982 to 1988*, FHWA Research Report 1131-3 (Texas Transportation Institute, College Station, Texas) 1990, as cited in Miller, P., and J. Moffet. *The Price of Mobility: Uncovering the Hidden Costs of Transportation* (Natural Resources Defense Council), October 1993.

Auto subsidies take the form of somewhat "hidden" subsidies, i.e., external costs including air pollution, parking, and accidents. Bus transit and rail modes, on the other hand, are the beneficiaries of direct governmental subsidies which are generally more easily identifiable.

The study by Miller and Moffet, though the data are relatively generalized for actual model inputs where local data are available, achieves another equally important goal. Their work demonstrates the various cost factors that should be accounted for in the evaluation of passenger transportation projects, and introduces methods for calculating such costs. The primary weakness of the report is precisely the scarcity of data and study resources that Miller and Moffet attempted to address by compiling this catalogue of information.

2.3.5 A Multimodal Transportation Evaluation Framework

More recently, Euritt and Harrison (Ref 11) proposed the multimodal transportation decision framework shown pictorially in Figure 2.1. They assert that in order to meet both federal and state economic and social objectives, transportation investment decisions must employ a total cost analysis. Such an analysis should include costs incurred not only in the sphere of transportation, but also in sustainable energy, the environment, and other areas of concern. Certainly, the inclusion of all system costs in analyzing transportation alternatives is likely to yield a transportation system significantly different from what currently exists. The objective of providing for a more efficient and rational investment of public transportation dollars necessitates the use of total cost strategy, a model which has its roots within the established field of transportation decision evaluation, as previously described. As shown in Figure 2.1, the key components to this total system cost analysis are infrastructure and support costs, modal ownership cost, and the cost of externalities.

The first group, infrastructure and support costs, includes expenses incurred during planning and design phases, infrastructure construction and reconstruction costs, land value savings, rehabilitation and maintenance costs, and control costs for operating the facility. Typically, infrastructure costs are governmental expenditures for terminals, links, and traffic control, and exclude facilities that are built and updated by private or commercial agencies. Depreciation and interest on the investment in the facility should be included when estimating infrastructure costs. The right-of-way cost component of the facility cost is the value of the land if it were used for another purpose. Rehabilitation cost includes all activities that help improve the road facility for the expected project life. Maintenance cost involves the general upkeep of the roadway surface and roadside to allow for safe traffic movement. Control cost includes the cost of law enforcement, legal activities, and signal control. Obtaining the actual cost of this last component is difficult, given that some may occur in non-transportation related agencies.

The second group, modal ownership costs, consists of vehicle costs and user fees incurred by owners of private vehicles or user fees incurred by public transit users. The expense of owning a vehicle is equal to the purchase costs of the vehicle, mainly the financial costs. Operating the vehicle requires financial outlays for taxes, fees, insurance, fuel, labor, and maintenance. The figure for the cost of fuel should not include the fuel tax, because it is included in the figure for taxes and fees. It is worth noting that some percentage of taxes and fees generated from the users is not used directly to finance transportation infrastructure. These taxes and fees for non-transportation purposes can be considered as an offset to costs paid by the taxpayer or general public for provision of transportation. Thus, the taxes and fees allocated for non-transportation related issues do not contribute to the total system-wide transportation costs.

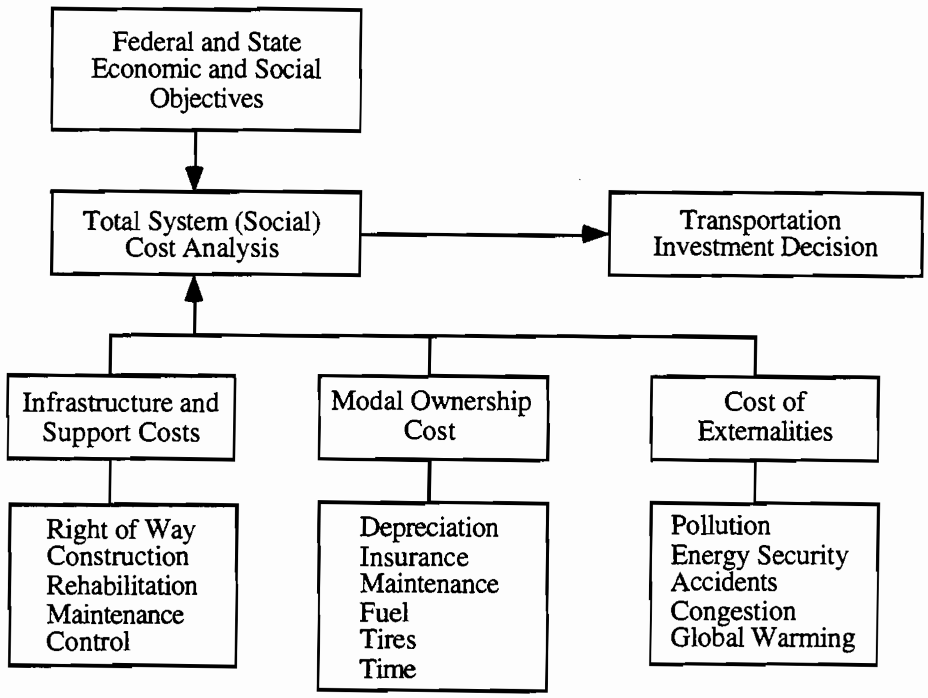

Figure 2.1. Multimodal Transportation Evaluation Model (with the cost of travel time included)

Source: Euritt, M. A. and Harrison, R., *A Framework for Evaluating Multimodal Transportation Investment in Texas,* Research Report 1282-2F, Center for Transportation Research, The University of Texas at Austin, 1994.

The final group, external costs, is considered as the economic impact on society resulting from the consequences (externalities) of transportation modal use. They include the environmental effects of air and water pollution, the cost of accidents, the cost of congestion, energy security cost, global warming, and aesthetic damage. These factors contribute to the overall cost of transportation and, yet, are seldom considered in the transportation planning process because of their abstract nature and effects, which can be difficult to measure. Air pollution costs are borne by the roadway users, but imposed on both system-benefiting users and non-benefiting public. The components considered to be included as part of the pollution cost are emissions of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM). Accident costs involve the expenses of fatalities and injuries, health care, property damage and other consequences of accidents. In order to avoid double counting, the part of the costs paid by user insurance premiums (included already in ownership costs) must be accounted for separately. Lastly, though in some studies, congestion costs are included in the ownership costs, the time delay experienced by commuters is costly to society as a whole. For instance, congestion costs such as interference with pedestrian movement, may impact on non-system users. Thus, the cost of congestion should be included in the total external costs of transportation.

2.3.6 Comparing Multimodal Alternatives in Major Travel Corridors (1994)[1]

DeCorla-Souza and Jensen-Fisher begin by discussing the need for a new approach for evaluating the cost-effectiveness of different transportation alternatives, and in particular alternatives of different modes. They discuss basic issues behind cost comparison, address the calculation of costs, introduce a simple spreadsheet-based cost estimation procedure, and demonstrate its application.

Through a discussion of the issues surrounding cross-modal, cost-effectiveness approach, the authors are both encouraging about its prospects and cautionary about its application. Much of the recent interest is due to the 1991 ISTEA act, both for its greater funding flexibility, and because it requires consideration of efficiency, socio-economic, and environmental factors.

Their introduction of a new approach is not only in response to such policy mandates, but serves also to address several limitations in traditional evaluative methods. For instance, the measurement of costs has often been applied non-uniformly between different modes. For the highway mode, for example, the costs borne by the private user, such as vehicle purchase, licensing, and maintenance, are typically not considered. In a similar fashion, the costs to roadway provision and maintenance for bus transit are usually not considered. And yet, DeCorla-Souza and Jensen-Fisher argue simply and directly: from the point of view of the society at large, it is irrelevant whether costs are borne by the private or public sectors, because the total cost is ultimately borne by all of society.

A third reason for a new approach concerns the need for a realistic base for comparison of alternatives. That is, according to the authors, the usual base for comparison is the "do nothing", or "no build," approach. This base, however, is unrealistic because in many cases users, particularly drivers, will change their travel behaviors as conditions worsen. Drivers will choose different routes, travel at a different time of day, or decide not to travel at all, for instance. On a larger scale and longer time frame, patterns of area growth and development may be affected, as well, which in turn affects mobility needs. The authors assert, therefore, the possibility that benefits of proposed alternatives may be inflated when compared to such an unrealistic base case. Accordingly, DeCorla-Souza and Jensen-Fisher's spreadsheet approach addresses the base case issue and other key issues including the calculation of the full costs of each alternative. Regarding the base case, they propose calculating the incremental costs of alternatives relative to the existing system, travel demand, and system performance. The costs of the do-nothing alternative may still be calculated according to the new approach, and likewise the incremental costs compared.

The authors discuss other aspects of their model which contribute to its applicability to decision-making. Effectiveness is measured in person-trips served; performance differences between alternatives are measured through cost. Their model may be used to examine travel demand management strategies as well as capacity- or facility-added strategies. In addition, they

[1]DeCorla-Souza, P., and R. Jensen-Fisher. "Comparing Multimodal Alternatives in Major Travel Corridors," *Transportation Research Record 1429* (Transportation Research Board), 1994.

assert that their model may be applied to entire urban areas when alternatives represent different aggregate future growth scenarios.

Of course, a substantial part of the article is devoted to calculation of costs. The authors propose the disaggregation of trips by peak and off-peak period trips, as well as by work, non-work, and freight person-trips, in order to allow for comparison of trip value to trip cost. This is because the value of a trip varies by its purpose. The model in its current state can only be applied to peak-period work purpose trips, according to the authors, and even in this explanation it is not clear how they place a value on these trips.

Transfer payments — such as transit fares, gasoline taxes, and highway tolls — are discussed in more detail as being irrelevant to the total cost of an alternative borne by society. Costs which are included in DeCorla-Souza and Jensen-Fisher's model include other costs with easily identified market-values, such as vehicle costs, highway facility costs, public transportation system costs, and safety and security costs. In addition, the authors include costs which typically have no market prices, for example travel time costs, environmental costs, and accident costs. They assert that values for some social impacts may not be able to be developed, and suggest that such impacts be listed for consideration but no attempt made to include a cost value for them in the final cost figure. The examples the authors provide for these impacts include national defense implications, community cohesion or interference with it, and accessibility for disadvantaged segments of the population.

DeCorla-Souza's and Jensen-Fisher's proposed model is a microcomputer spreadsheet to compute these costs on a per-unit basis. The necessary base inputs are travel model inputs — person trips generated, travel miles as assigned by mode, and travel minutes as computed in traffic assignment. The authors demonstrate their model by examining a peak-period work travel market for a multimodal transportation corridor study — Interstate 15 in the Salt Lake City, Utah, metropolitan area. The alternatives they consider are:

1. the addition of two mixed-flow lanes in each direction;
2. the addition of one mixed-flow lane in each direction and one reversible High Occupancy Vehicle (HOV) lane; and
3. a light rail line on existing rail right-of-way parallel to I-15, accompanied by various Transportation System Management improvements.

The results of the demonstration application are shown in tabular format. The comparison is made between alternatives based upon daily savings. According to the authors' calculations, the light rail alternative entails the least daily cost among the three alternatives.

DeCorla-Souza and Jensen-Fisher conclude their presentation on a cautionary note. They explain again that the model, still in its simple spreadsheet form, has many limitations. For example, their approach attempts to monetize social and environmental costs which are highly subjective and sensitive to the community in which the model is being implemented. The model in its current form is useful only as a screening tool and not yet as a detailed application needed for major investment analysis. Discount rates, as applied to highway and other capital costs, have a significant impact on results, necessitating the inclusion of sensitivity analysis as part of evaluation. Valuation of time is an issue still under debate in many planning circles. Finally, the spreadsheet presented evaluates only a single target year.

This 1994 article by DeCorla-Souza and Jensen-Fisher, furnishing both an introduction to some of the issues inherent in full-cost comparison and a demonstration of a simplified full-cost application, provides a good stepping-off point for a discussion of some basic issues inherent in the full-cost debate.

2.4 GENERAL FULL-COST APPROACH ISSUES

The above review of literature demonstrated both that significant strides have been made toward the capability of evaluating the full costs of cross-modal transportation alternatives and that there is still much debate regarding the best approach to use. This debate centers around two primary issues: the relationship of full cost analysis to benefit/cost analysis and the distinction between societal gains and transfers.

2.4.1 The Difference Between Full-Cost and Benefit/Cost Analysis

Full-cost analysis is closely related to benefit/cost analysis, a decision making tool which dates back to the 1930s. Benefit/cost analysis measures whether the benefits of a particular decision outweigh its costs and therefore represents a gain (or loss) to society. If alternatives are being compared, the one with the greatest benefit-to-cost ratio is preferable. Both sides of the equation, benefits and costs, are measured in a quantifiable term, almost always money. Because some costs and benefits do not demonstrate easily discernible market values — the value of life is one example -- benefit/cost analysis does have skeptics. Nonetheless, it remains popular in the planning field because of its continued usefulness as a quantitative evaluative tool.

For transportation decisions, a benefit/cost approach is less applicable owing to the lack of true benefits. For example, it has been customary to assign time savings to the benefit side of the equation. However, time savings is really just another way of saying the alternative demonstrates less time expended on the cost side of the equation. Likewise, reduced air pollution is frequently mentioned as a benefit of a particular transportation alternative, and yet similarly represents lower environmental cost. Because transportation is not a good in and of itself, but a service similar to a utility which gets us where we need to go, it can only be accurately evaluated in terms of cost, which the full-cost approach does.

One final analogy may help explain this important point. Karen Consumer goes to the mall to shop and sees the exact same dress in two different stores. In one store, Dress A is regularly priced at $200. At the second store, Dress B is on sale for $100. Karen Consumer buys Dress B and comes home to boast to her mother that she "saved" $100. Karen might be able to persuade her mother that a "benefit" of buying Dress B is that it cost $100 less than Dress A. In actuality, there is no true difference in the positive value of Dress A over Dress B, however. The difference is in the negative value — Dress B *costs* more than Dress A. By discussing this contrived "benefit" of Dress A, Karen Consumer may be able to brush aside the real issue, which is that no money was actually "saved", but $100 was spent. Discussing difference in cost as a benefit can easily make a multimillion dollar facility seem like a real "bargain," if only because it is compared to a facility which costs several *billion* dollars.

2.4.2 The Debate Concerning Societal Gains v. Transfers

An efficient and dependable transportation system is a necessity for a healthy economy, a fact which few would deny. Yet one of the hottest debates in the transportation decision-making process is the issue concerning the local economic impact of a transportation corridor, both its ultimate use and its implementation. That is, the transportation decision matrix is often overwhelmed by the economic justifications for projects, losing sight of the reality that transportation is itself merely a means and not an end.

The implication is that the goal changes from providing efficient transportation (as a means to a healthy economy) to generating economic benefit (the transportation project itself becomes the economic end). If the goal is transportation, then the project which results in the greatest transportation improvement at the lowest cost is that which should be chosen. This decision presumably results in a gain for society due to increased cost effectiveness and savings.

If, instead, the goal is employment (as, for example, was the case with the Civilian Conservation Core funded under the presidency of Franklin D. Roosevelt), then the most labor-intensive construction and operation project should be chosen, with as little money diverted to capital expenditure as possible. Under this scenario, there is no gain for society but rather a "transfer" of funds from one sector (the governmental agency) to another (workers). For the sake of practicality, as well, such a direct transfer of funds is much wiser than the gamble that a certain corridor will economically revitalize a community.

Amplification effects (also known as the Multiplier Effect) are another popular way to measure the "benefits" of particular transportation alternatives. Economic amplification presumably does result, yet cannot be considered an *added* benefit if the money would be released into the economy anyway if spent on another transportation project or even in another sector of the economy.

In theory, few decision makers would fund a transportation project merely as a means to greater employment — after all, if the money is to be spent, these jobs could be funded through any sector. In reality, many decision makers are swayed by the economic benefit that a particular project offers to their community, rather than by the transportation necessity.

For example, the trucking industry is a big proponent of roadway projects, claiming that improved roadways positively impact the economy. Yet, from a wider perspective, if society pays more for transporting goods by truck than by other modes such as rail, then all of society may be bearing a higher price for that transportation decision. The "jobs produced" concept is wildly popular among politicians, the public, and even many policy analysts, and yet, having little to do with cost effectiveness or savings, this criterion could not be a more inappropriate measurement in a project evaluation.

The pros and cons that are apparent in the discussion above revolve around an issue that has less to do with transportation and more to do with how wealth can be redistributed and interests subsidized. In an additional example, if community leaders in a town proposed to tax the entire town to redevelop one neighborhood, the debate might quickly polarize between the winners (people who live in the receiving part of town, or at least people who own property there) and the losers. The losers are everyone else who pays the tax but will not directly benefit from the improvements or, at least, would benefit equally if the money was spent in their own part of town (improvements which would bring outside dollars into town such as for tourism are not under discussion). Community leaders might try to persuade a majority that they will indirectly benefit from these improvements, but the debate may still center on this outright transfer of funds from some people to others.

Now, instead of this scenario as described above, how much easier is it to perform this transfer indirectly? Instead of improving properties directly, leaders may build a road next to it, which increases (in most cases) the property's accessibility and value. This road or other such transportation facility may cost a little more than building it in another location, but the "benefit" to this neighborhood counts in its favor in the traditional decision matrix. Overall, this indirect transfer of funds from the rest of the town to this one neighborhood may cost a little more than a direct transfer of funds (owing to the cost of constructing the facility and maintenance) but fewer debates arise regarding the construction of a road than the direct transfer of funds from one group of citizens to another. Chances are, the new road was funded out of existing transportation apportionments, so the average citizen never really finds out that there was a debate at all about where to spend these transportation tax dollars. The average citizen assumes that transportation tax dollars are allocated to improve the efficiency of transportation and therefore to reduce the cost of transportation to society at large; this may not necessarily be the case.

One final argument for the strict consideration of cost with regard to transportation alternatives: If transportation efficiency and reduced overall cost to society were the only factors considered in decision-making, then society would spend less on this intangible utility expense (that is, transportation) and would have more money left over for economic redevelopment projects. On the other hand, a community may spend more dollars up front because of a project's predicted economic benefits. If the community loses this gamble, it not only loses the money it could have spent on more straightforward (and predictable) investments, but it continues to pay the higher cost of a less efficient transportation corridor and/or system.

It is under the assumption that transportation alternatives should be measured in terms of their overall cost to society that full-cost models have been developed. The debate regarding economic transfers does not end with the above discussion, but the need for straightforward evaluative tools to aid planners and decision makers is clear. Chapter 3 introduces MODECOST, a full-cost model developed by the Center for Transportation Research of The University of Texas at Austin.

CHAPTER 3. IDENTIFICATION AND VALUATION OF COSTS

3.1 INTRODUCTION

The previous section described several frameworks for evaluating multimodal transportation costs. This chapter identifies various transportation cost components and their estimated values, as found in the literature. It also includes a section that describes various methods employed for the valuation of externalities or social costs.

3.2 IDENTIFICATION OF FULL SOCIETAL COSTS[1]

The study of the full costs of transportation has become a popular field of inquiry only in the past few years. Certain components of the total cost of transportation, such as federal expenditures on road construction and maintenance, and personal expenditures on auto ownership, have been well studied. But estimates of other costs, especially the delays caused by congestion, remain somewhat speculative, and costs such as those associated with transportation's impact on pollution remain unquantified.

Figure 3.1 illustrates the components of the full "societal" costs of a transportation system. These costs include not only the capital and maintenance costs of public infrastructure, but also costs borne by private users as well as those costs dubbed "social" costs or "externalities."

External costs include expenditures related to parking, accidents, water pollution, air pollution, and noise. Congestion cost not only impacts individuals using the system coincidentally, but also interferes with pedestrian movement, and in turn impacts individuals not using the highway system. The branch of Figure 3.1 called "External Cost to Non-Benefiting Public" brings attention to the fact that some impacts such as acid rain may impact populations that do not benefit at all from the mobility that is the source of the externality. Hanson argues that urban residents benefit from their personal travel and that of others. However, in a world where the vast majority of households do not own a motor vehicle, the impact of climatic change on the non-benefiting populations cannot be neglected.

The costs listed under the "Capital and Non-Capital" category include local police and fire services, right-of-way, construction, rehabilitation, and maintenance. The payments of these costs come from both user fees and tax transfers (as well as from subsidies). The "Private" costs category includes the vehicle depreciation and the operating cost — e.g., routine maintenance, fuel, and insurance.

3.2.1 Highway Capital and Non-Capital Costs

Expenditures by all levels of government — federal, state, and local — include infrastructure construction and reconstruction, land value savings, rehabilitation and maintenance costs, and the control costs required for operating the facility. State and local governments, with assistance from the federal government, provide capital investment in the construction of transit

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[1]Hanson, M. E. (1992).

lines and the purchase of transit vehicles. In addition, less visible government support for transportation takes a variety of forms. For instance, each state operates a department to administer licenses, registration, and driver education; moreover, there are police, fire, and justice system expenditures that address vehicle-related incidents.

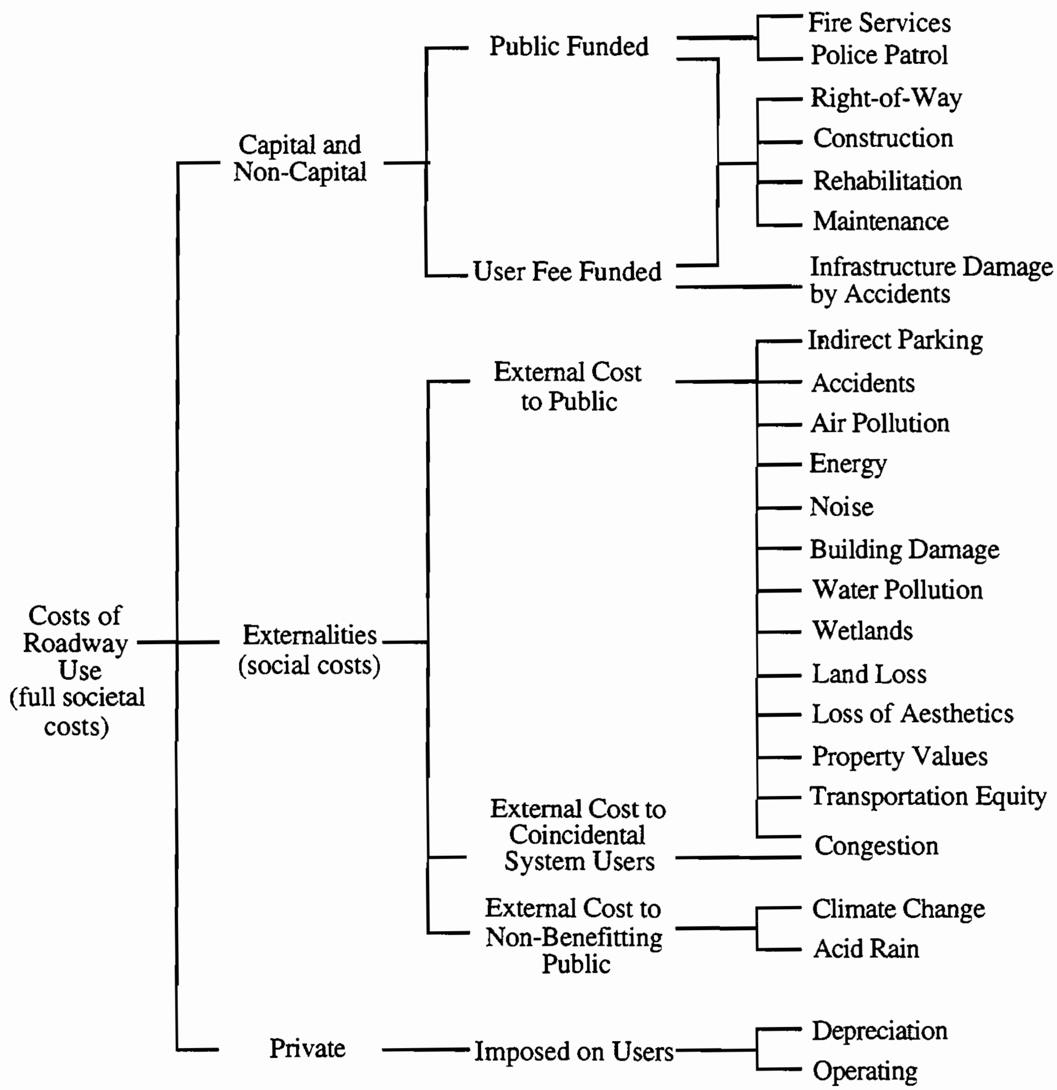

Figure 3.1 Costs of Roadway Use[1]

[1]This figure is the modification of the original work by Hanson (1992). Some of the cost components are added into his diagram.

Typically, infrastructure costs are governmental expenditures for terminals, links, and traffic control (facilities built and updated by private or commercial companies are of course excluded). When estimating infrastructure costs, depreciation and interest on the investment in the facility should be included. When applicable, an interest charge on the value of land can also be included in the costs.

The land-cost component of the facility cost should reflect the opportunity cost of the land that was used for transportation infrastructure. To determine the land value, the land area used for transportation purposes is priced as appropriate percentages of farmland or residential property. This total value is converted to an annual rate and the land cost is allocated to vehicle types according to total passenger-miles traveled.

The rehabilitation cost of the roadway represents the ongoing cost of pavement wear. It includes all activities that improve the road surface and that ensure that the roadway will remain in service for the expected project life. Maintenance cost usually refers to the costs incurred during routine annual care of the roadway. It involves the general upkeep of the roadway surface and roadside to allow for safe traffic movement. Both rehabilitation and maintenance cost estimates depend on vehicle loads and traffic, as well as on facility location. The former plays a critical role in determining rehabilitation and maintenance costs. Environmental exposure to rain, snow, ice, and road salt may play a part in facility deterioration, particularly in extreme climates. Control costs include the costs of police enforcement, driver/vehicle enforcement, and basic control programs for passenger cars. Obtaining actual cost data to accurately account for all control services is difficult because these expenditures occur in non-transportation-related agencies. Capital expenditures associated with roadway improvements include land acquisition and other right-of-way costs, preliminary and construction engineering, and the resurfacing, reconstruction, rehabilitation, and restoration costs of roadways and structures. These totaled $38.7 billion in 1992; for every vehicle-mile of travel (VMT), $0.0173 was spent on roadway capital improvements.[1] Non-capital expenditures include maintenance and operation of highways, administration, roadway law enforcement, safety, and debt service on bonds and notes. The bill for the public sector was $45.63 billion in 1992, or $0.0204 per VMT.[2] For every person-mile of travel (PMT), $0.0223 was spent on roadway capital and non-capital costs.[3]

Bus transit system figures were not as great. Miller and Moffet[4] estimated that the annual capital cost and operating expenses for buses in 1990 were $3.11 billion and $10.99 billion, respectively, which converts to $0.32 per PMT. The fare revenue in the same year reached $5.20 billion. The total expenditures during the same period for rail were $11.47 billion: $3.66 billion for capital cost and $7.81 billion for operating expenses, or $0.45 per PMT, for which users paid $3.61 billion in fare. The Royal Commission[5] reported that in British Columbia the unit infrastructure cost is $0.0344 per PMT for automobile, and $0.00492 per PMT for bus users. The

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[1]Calculated from *Highway Statistics*, U.S. Department of Transportation, Washington, D.C., 1992.
[2]Calculated from *Highway Statistics*, U.S. Department of Transportation, Washington, D.C., 1992.
[3]Calculated from *Highway Statistics*, U.S. Department of Transportation, Washington, D.C., 1992.
[4]Miller, P., and J. Moffet (1993).
[5]Royal Commission on National Passenger Transportation (1992).

fact that the unit cost for bus users is much lower than that observed in the U.S. may reflect Canada's higher bus occupancy.

In addition to the expenditures on capital construction, road and bridge maintenance, traffic police, and administration, there are a number of additional vehicle-use costs incurred at the local level. These variable costs include expenditures for traffic control, parking and moving violations requiring police, parking lot administration, driver education, promotional materials, disposal of waste oil, tires, batteries, and other toxic products, and drainage system and local water clean-up facilities. These services require a wide range of public offices, including public utilities, public health, and city and local planning offices. Few of these expenses appear in transportation budgets. Miller and Moffet[1] estimated that the total costs were around $11 billion per year. (The estimates came from a previous study by the FHWA[2].) Since the estimates include the local policing costs, which have been accounted for earlier in the operation cost, Miller and Moffet corrected the figure to $8 billion per year, or $0.0026 per PMT for automobile users. There are no reliable data to estimate these costs for rail and bus transportation. Most of these costs are probably much lower on a per-PMT basis than the corresponding auto costs not only because of the centralized nature of most rail and bus facilities, but also because of the lower number of vehicles involved. In the same report, Miller and Moffet[3] gave the approximate number at about $0.0013 per PMT, or $60 million for buses, and $30 million for rail.

3.2.2 Private User Cost

The auto user ownership and operation costs include vehicle purchase and financing, operating and maintenance cost (i.e., gas, oil, tires, repair, and parts), and insurance. A less visible cost is the additional parking expense for a garage at home, which is included in the pricing of housing.

Personal auto ownership costs vary considerably, depending on car type and individual driving pattern. The running speed as well as road and driving conditions are also critical to auto operating costs. In addition, parking and tolls vary from region to region. Financial charges, representing foregone returns at an interest rate for an amount of money, depend on the financial rate, finance period, and amount financed.

The FHWA's report, "Cost of Owning and Operating Automobiles, Vans and Light Trucks–1991," is a good example of a comprehensive user-cost study. The major ownership cost elements are depreciation; finance charges; insurance costs; registration, title, and inspection fees; and vehicle taxes. Operating costs are classified as: (1) scheduled maintenance, (2) unscheduled repairs and maintenance, (3) fuel, (4) oil, (5) tires, (6) parking and tolls, and (7) taxes.

The definition of depreciation is "loss of value of the vehicle during its lifetime due to passage of time, its mechanical and physical condition, and the number of miles it is driven." For a full-sized automobile, the average annual depreciation is estimated to be $0.1345 per mile. This

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[1]Miller, P., and J. Moffet (1993).
[2]Federal Highway Administration. *Federal Highway Cost Allocation Study*, U.S. Department of Transportation, Washington, D.C., 1982.
[3]Miller, P., and J. Moffet (1993).

is based on a purchase price of $17,784, ownership by the same person for 12 years, and an average vehicle lifetime mileage of 128,500. Based on a 10.5 percent interest rate with a 4-year financing term and a 25 percent down payment, the finance charge for the same vehicle is $0.025 per mile. Obviously, various alternatives would affect the average vehicle finance charge.

Similarly, insurance costs depend on the type of vehicle and coverage desired. The authors of this FHWA report assumed that vehicles have the following coverage: $20,000/$40,000 bodily injury, $10,000 property damage, $2,500 personal injury protection, and $20,000/$40,000/$10,000 uninsured motorist coverage. It is also assumed that vehicles have a $100 comprehensive deductible and a $250 collision deductible. Assuming that this insurance coverage remains in effect over the 12-year period, a full-sized automobile incurs an average cost of $0.0717 per mile in insurance costs.

Registration, title, and inspection fees also vary with the pricing schemes of each state. The FHWA report used the average price in the study area, Maryland, to estimate the total cost. Using this figure, the owner of a full-sized automobile will pay an average of $0.0038 per mile over the life of the auto. Based on a vehicle purchase price of $17,784, the vehicle tax is $889.20, which averages to $0.0069 per mile over the 12-year period.

Scheduled maintenance is assumed to be regularly required maintenance, such as oil changes and tune-ups, performed by professional mechanics in accordance with recommendations in the vehicle owner's manual. Unscheduled maintenance repairs are estimated, based on 1989 total cost for repairs, and adjusted for various classes of vehicles. A full-sized automobile incurs an average of $0.0233 per mile for scheduled maintenance and $0.0196 per mile for unscheduled maintenance.

Fuel, oil, and tires are required for the operation of motor vehicles. A cost of $1.196 per gallon, including federal and state taxes, for unleaded regular gasoline is used in the study. A full-sized automobile averages 17.99 miles per gallon, resulting in an average cost of $0.0485 per mile for fuel, not including federal and state gasoline taxes. Oil changes are assumed at 7,500 mile intervals. The cost is estimated to be $0.0016 per mile. Tires are assumed to be replaced every 40,000 miles, or for the years 4, 7, and 12 during ownership of a vehicle. The average cost for tires is approximately $0.0096 per mile.

Parking costs account for the use of metered parking spaces and parking garages. Tolls include the cost of driving on toll roads, tunnels, or bridges. These costs are to be approximately $0.0129 per mile. The tax component of the study included the taxes from fuel, oil, tires, and maintenance. For a full-sized automobile, taxes are approximately $0.0079 per mile for federal taxes and $0.0131 per mile for state taxes. Overall the owning and operating costs incurred on a full-sized automobile owner are $0.3784 per mile. Meanwhile the report presents estimates of annual costs for seven other vehicle classes, tracing the incurred expenses through a 12-year vehicle lifetime. The seven other vehicle classes examined in the study were: (1) subcompact automobiles, (2) compact automobiles, (3) intermediate automobiles, (4) compact pickup trucks, (5) full-sized pickup trucks, (6) minivans, and (7) full-size vans. Table 3.1 summarizes the study findings, with the costs reported as the average owning and operating costs over 12 years in dollars per mile.

Table 3.1 Costs of Owning and Operating a 1991 Vehicle ($ per mile)

Vehicle Type	Ownership Cost	Operating Cost	Total Cost
Subcompact Automobile	0.1800	0.1066	0.2866
Compact Automobile	0.1807	0.1148	0.2955
Intermediate Automobile	0.2057	0.1267	0.3324
Full-Sized Automobile	0.2419	0.1365	0.3784
Compact Pickup Truck	0.1843	0.1195	0.3038
Full-Sized Pickup Truck	0.1972	0.1528	0.3500
Minivan	0.2183	0.1342	0.3525
Full-Sized Van	0.2667	0.1791	0.4458

Source: Federal Highway Administration. *Cost of Owning & Operating Automobiles, Vans & Light Trucks 1991*, U.S. Department of Transportation, Washington, D.C., 1992.

MVMA[1] estimated personal auto user costs around $0.25 per PMT, indicating a total annual cost of $775 billion.[2] The estimate assumes that depreciation and operating costs are related in a linear fashion to mileage, regardless of other conditions. Regarding other modes of travel, transit riders do not directly pay the capital and operating costs of their travel. The only cost associated with transit ridership is fare. Fare revenues for buses and rail are $0.12 per PMT and $0.14 per PMT, respectively[3]. Although included in the discussion, it is important to remember that taxes, fees, and fares are transfers and not costs as pertaining to full-cost analysis. Said in another way, transportation costs are recovered through the user taxes and fees, at least in principle.

3.3 EXTERNALITIES OR SOCIAL COSTS

3.3.1 Valuation of Social Costs[1]

Assigning a value to social costs sometimes is difficult since it may fail to include all internal and external costs that are imposed on other system users or on the non-benefiting public. This section reviews the techniques used to measure the social costs of using urban roadways.

Based on a review of existing literature, the valuation of full costs embraces a number of techniques that represent different methods for placing monetary measures on the social costs of using urban roadways. The existing approaches can be broadly divided into direct and indirect valuation methods. As Hanson has indicated:

> Direct valuation methods rely on unveiling existing but hidden preferences. Markets are necessary to uncover these preferences, thus direct valuation methods

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[1]Motor Vehicle Manufacturers Association. *Facts & Figures '92*, 1992.

[2]Miller, P., and J. Moffet (1993).

[3]Miller, P., and J. Moffet (1993).

[1]This section is drawn entirely from M. E. Hanson's *Results of Literature Survey and Summary of Findings: The Nature and Magnitude of Social Costs of Urban Roadway Use,* prepared for FHWA, Contract ID DTFH61-91-P-01345, Resource Management Associates of Madison, Inc., Madison, WI, 1992.

> are all market-based. In contrast, indirect valuation methods do not try to infer preferences but instead focus on the physical linkages between environmental factors and a market.[1]

This technique attempts to assess actual environmental impacts, via "dose-response" relationships, in terms of human or animal health, materials, or vegetation; it then assigns a monetary value to those impacts.

As shown in Figure 3.2, Hanson divided the direct valuation methods into two sub-methods, i.e., surrogate markets and experimental markets. According to Hanson, "Surrogate market approaches use markets in which goods and services or factors are traded and in which environmental costs are attributes of those goods or factors."

One of the processes that uses surrogate markets is the hedonic property price method, or willingness-to-pay method. In the housing market, for example, this method tries to determine the loss of property values resulting from a particular environmental effect. Then the method tries to infer the monetary measure that people are willing to pay to avoid the environmental effect.

There are several problems with the hedonic method. First, all variables that may affect property values must be included in the analysis in order to avoid biased estimates, though some of the variables may be hard to measure and highly correlated. Second, the analysis is often sensitive to the functional form chosen by the researchers. And, third, the method assumes that people are able to choose their preferences, which may not be the case.

Both wage-risk studies and travel cost studies belong to the hedonic method. Wage-risk studies determine the difference between high-risk jobs and low-risk jobs, and then assign a cost to the probability of death or injury. Travel cost studies estimate the cost of time people spend on travel. The basic question it raises is how to determine the monetary value of time. Often researchers use a person's wage rate as the measure, which implicitly assumes that the time spent on the road would otherwise have been spent working. Since most working people work eight hours a day, it is more likely that the traveling time is taken out of leisure time.

The other direct valuation is through experimental market, such as surveys and interviews. Individuals being surveyed or interviewed indicate how much they are willing to pay to avoid the effect if it exists. The advantage of this method is its flexibility and applicability to any market. However, this method often heavily depends on the questions designed and the interview process itself. Also, as Hanson has indicated, the method

> ...is flawed by a number of biases through the design of the survey, the sampling procedure and/or the interviewing process. Also creating artificial markets through hypothetical questions lacks the true incentives of a market.[2]

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[1]Hanson, M. E. (1992).

[2]Hansen, M. E. (1992).

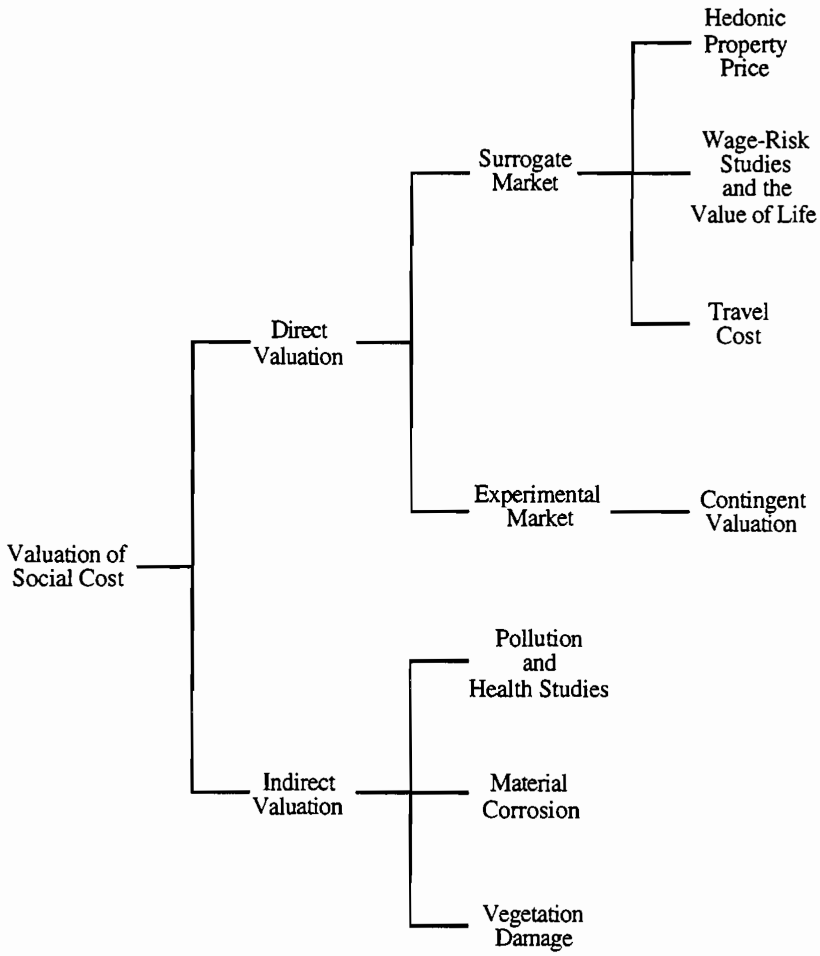

Figure 3.2 Analytical Approaches for the Valuation of Social Costs

Source: Hanson, M. E., *Results of Literature Survey and Summary of Findings: The Nature and Magnitude of Social Costs of Urban Roadway Use*, prepared for FHWA, Contract ID DTFH61-91-P-01345, Resource Management Associates of Madison, Inc., Madison, WI, 1992.

Unlike the direct valuation methods, the indirect valuation methods try to focus on the damage value actually experienced in terms of health, material, or vegetation. For example, in the evaluation of pollution costs from emissions, indirect valuation methods link environmental factors with surrogate or experimental markets to determine the costs in monetary terms. This method is desirable when the linkages are quite well understood, i.e., the effect of carbon monoxide on ground level ozone reduction. When the linkages are uncertain or extremely difficult to find, such as in the case of climate change (which links to a number of factors), this method becomes unreliable.

3.3.2 Indirect Parking Costs

Parking costs are often ignored as a transportation cost because they are paid and subsidized in a variety of ways. Several costs associated with parking include (1) user costs for parking lots or metered spaces; (2) employer subsidies to provide free parking to their employees; (3) capital and operating costs of purchasing land and constructing and maintaining parking lots; and (4) tax revenues that the government forgoes by failing to tax the fringe benefit value of free parking. Except for the parking cost paid by users, all the other charges are invisible costs and often represent a subsidy to the urban driver. It is estimated that approximately 90 percent of all employers in the U.S. provide some free or subsidized parking to employees.[1]

Employers offer free parking to employees partly because this fringe benefit is tax-free federally. If an employer provided an employee with an extra $2,000 of take-home salary instead of a parking space as a fringe benefit at about $2,000 per year in Washington, D.C. area, he would have to pay $4,400 per year, including $1,334 in federal, state, and local taxes, $572 in social security, and $494 in pension contributions and other benefits.[2] It therefore costs employers far less to offer "free" parking than the equivalent salary increase.

Subsidized parking not only imposes subsidies on society, but also encourages driving to work. This extra driving, in turn, creates additional pollution, congestion delay, and fuel consumption. Subsidized parking also indirectly affects urban land use. That is, urban planners often base the minimum number of parking spaces on the parking demand represented by employer-provided parking and inflated zoning requirements for total parking. Many employees welcome free parking benefits, but others who live near work or prefer other modes of transport might not need or want free parking. Without any doubt, free parking encourages solo driving.

The value of parking subsidies is difficult to assess. As cited by Miller and Moffet,[3] DeLuchi estimated a total annual parking subsidy of $100 billion, or $0.032 per PMT. The best study about parking cost is the Apogee study.[4] That study examines the various economic non-residential parking by type of cost — user, governmental, and societal. User costs include paying for a parking spot, such as at work or at a downtown shopping center. Governmental costs are the loss of revenue to the government for subsidizing employer-paid automobile parking. Societal costs are the economic cost of non-residential off-street automobile parking not paid by users, housing, or government costs. It is estimated that the non-residential parking cost ranges from $0.025 per PMT to $0.10 per PMT for single-occupancy-vehicle, and $0.01 per PMT to $0.04 per PMT for high-occupancy-vehicle in Portland and Boston.

In the same report, Apogee gave the estimates of residential parking costs. Residential parking costs represent the amount travelers spend to keep cars at their homes, and is calculated separately from non-residential parking costs. The estimates range from $0.012 per PMT to

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[1]Wegman, F. *The Cost Effectiveness of Private Ridesharing Programs*, Transportation Center, University of Tennessee. As cited in P. Miller and J. Moffet (1993).
[2]MacKenzie, J. J., R. C. Dower, and D. D. T. Chen (1992).
[3]Miller, P., and J. Moffet (1993).
[4]Apogee Research Inc. (1994).

$0.157 per PMT for single-occupancy-vehicle, and $0.005 per PMT to $0.063 per PMT for high-occupancy-vehicle, depending on locations. These estimates are summarized in Table 3.2.

Table 3.2 Parking Cost (cents per PMT)

	Single-Occupancy-Vehicle				High-Occupancy-Vehicle			
	Non-Residential			Resi-dential	Non-Residential			Resi-dential
	User	Gvt.	Societal		User	Gvt.	Societal	
Boston	0.3–4.7	0.1–1.0	2.9–5.1	6.9–15.7	0.1–1.9	0.1–0.4	1.2–2.0	2.8–6.3
Portland	0.1–4.0	0.1–1.0	2.5–5.0	1.2–5.8	0.1–1.6	0.1–0.4	1.0–2.0	0.5–2.3

Source: Apogee Research Inc. *The Cost of Transportation: Final Report*, Prepared for Conservation Law Foundation, 1994.

In its analysis of the "full" cost of various modes of passenger transport in the British Columbia Lower Mainland region, KPMG[1] included the value of land used for parking and driveways, as well as building costs of garages and parking lots, in the residential parking cost. The result is $0.60 per VMT, which is much higher than its U.S. counterpart. In addition, they estimated the opportunity cost of land used by government facilities to provide free parking to employees and visitors, and the costs involved with financing and maintaining a parking lot. The calculated cost per VMT is about $0.005, of which municipalities and provincial governments are responsible for 13 percent and 87 percent, respectively. The opportunity cost of land used by commercial establishments to provide free parking to customers and by all business to provide parking to employees is $0.016 per VMT in Vancouver.

3.3.3 Congestion

Congestion within metropolitan areas has long been recognized as a severe problem. The problem has now spread to the outer suburbs of many cities, for example, in the San Francisco Bay area. The situation is such that, in many surveys, travelers cite congestion as the top problem.[2] Analyses of congestion have generally been divided into two estimates — recurring and incident. Recurrent delay occurs as a result of normal daily operations. Incident delay is caused by accidents, breakdowns, work zones, or other occurrences which decrease roadway capacity. There are a number of forces responsible for this traffic congestion problem. First, the current practice of urban land planning in suburbs and metropolitan areas has increased the need to drive for almost all activities. Second, automobiles have become increasingly affordable to almost all families in the U.S. Finally, changes in the employment base and distribution of goods, services, as well as increased travel by trucks, have changed travel patterns.

[1]KPMG. *The Cost of Transporting People In the British Columbia Lower Mainland*, Peat Marwick Stevenson & Kellogg Management Consultants, prepared for TRANSPORT 2021, Vancouver, 1993.
[2]Eno Foundation. "Report of the 20th Annual Joint Conference of the Eno Foundation Board of Directors and Board of Consultants," *Transportation Quarterly*, 42/1, 1988.

One of the main problems with measuring delay costs is the question of how to attribute a dollar value to travel time. For example, there is much debate as to whether time should be valued equally regardless of the traveler. Also, it is possible that people find travel more or less onerous depending on trip purpose — time spent commuting and traveling on the job may be more valuable than time spent traveling for leisure travel. Typically, non-work travel time is valued at between 20–50 percent of the average wage rate.

There are several different approaches to estimate the congestion costs. One measures the user costs that would have to be imposed in order to reduce congestion to an acceptable level.[1] Yet as control costs, user costs may not reflect the damage costs caused by congestion. The second approach estimates the cost of providing the additional capacity required to eliminate the congested condition. Using this approach, Lomax et al.[2] developed measures of congestion in the 50 largest cities in the U.S., and estimated the monetary costs of delay. In 1988 and 1989, the delay costs plus the higher insurance premiums due to congestion totaled $63.2 billion. The excessive fuel use caused by delay totaled $11.1 billion over the 2-year period. Drawbacks to this approach include its failure to consider the possibility of increased demand resulting from additional roads and the fact that it measures control costs instead of damage costs. The third approach is to directly estimate the costs imposed on society by congestion. These include the increased emissions caused by slower traffic and longer travel time; productivity loss due to human and freight delay; and higher vehicle operating cost. In this section we only consider delay cost, since all others will be reported elsewhere in the report.

In a 1989 report, the U.S. General Accounting Office (GAO) estimated that the congestion-related costs of delay for the nation total between $19.4 billion and $22.9 billion on all roadways.[3] The GAO also indicated the relationship between congestion and a variety of adverse physiological conditions. For example, congestion can increase driver stress, which can result in aggressive behavior and adverse physiological reactions, the costs of which were unquantified. In 1989 Los Angeles bore the highest congestion cost in the U.S. — an astonishing $7 billion. Congestion costs per vehicle were highest in Washington, D.C., at $1,280, and congestion costs per capita in San Bernardino-Riverside, CA, at $840.[4]

Translating congestion costs into a unit cost per PMT nationwide is impractical because congestion costs vary considerably by location and time of day. The cost may be zero on many rural highways, and may be 10 times the average over all roads in some major metropolitan areas. Nevertheless, NRDC[5] offered a figure of $0.0035 per PMT spread across all drivers. This corresponds to an $11 billion annual congestion delay cost, which may be an overestimate. Regarding other modes of transportation, congestion can have greater costs for transit passengers

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[1]Federal Highway Administration (1982).
[2]Lomax, T. J., D. L. Bullard, and J. W. Hanks. *The Impact of Declining Mobility in Major Texas and Other U.S. Cities*, Research Report 431-1F, TTI, 1989.
[3]General Accounting Office. *Traffic Congestion: Trends, Measures and Effects. Report to the Chairman*, Subcommittee on Transportation and Related Agencies, Committee on Appropriations, U.S. Senate, GAO/PMED-90-1, 1989.
[4]Apogee Research Inc. (1994).
[5]Miller, P., and J. Moffet (1993).

than for automobile users. NRDC[1] indicted that every additional minute of roadway congestion causes about two extra minutes of delay for bus travelers. Congestion costs are not estimated for buses or rail in specific figures.

3.3.4 Accident Costs Not Borne by Drivers

Accidents are an unavoidable part of transportation. Motor vehicle crashes claim 39,000 lives and injure about 3.5 million each year.[2] Accidents also involve expenses for damage to private property and minor personal injuries, either through payment of insurance premiums or because the individual responsible for the damage pays for it directly. The cost paid by insurance is covered by the cost of insurance premiums and is included in the expenses of personal user cost.

Accident cost depends on the severity and frequency of accidents. In general, the rates paid for severity of accidents by insurance companies tend to undervalue major loss, especially fatalities.[3] There are several approaches estimating appropriate value for loss of life. The gross output approach equates the major cost of an accident with the discounted present value of the victim's expected future income. This does not necessarily reflect the way people value their lives or the lives of others. For instance, most people may value safety more out of an aversion to injury or death than out of a wish to preserve future levels of income. A second approach relies on the trade off between wealth and safety. The measure is problematic because it relies heavily on labor markets. A better approach is to measure society's aggregate willingness to pay for safety, a method that has been adopted by some European countries and somewhat in the U.S.

The study by Miller et al.[4] developed a measure of accident costs on a per-victim and per-vehicle basis. The costs were presented in terms of the Maximum Abbreviated Injury Scale (MAIS). The scale differentiates injuries by the threat they pose to life. The MAIS ranks injuries on a scale from 0 to 6: no injury (MAIS 0), minor injury (MAIS 1), moderate injury (MAIS 2), serious injury (MAIS 3), severe injury (MAIS 4), critical injury (MAIS 5), and fatality (MAIS 6). These rates are shown in Table 3.3.

Table 3.3 Costs Per-Victim by MAIS Categories (1980 Dollars)

Scale	0	1	2	3	4	5	6
Direct	716	1,601	3,442	8,089	18,467	138,684	18,294
Indirect	132	690	1,165	2,217	32,564	122,897	724,227
Total	848	2,291	4,607	10,306	51,031	261,581	742,521

Source: Miller, T. R., K. A. Reinert, and B. E. Whiting. *Alternative Approaches to Accident Cost Concepts: State of the Art*, Report FHWA/RD-83/079, FHWA, U.S. Department of Transportation, 1984.

[1]Miller, P., and J. Moffet (1993).
[2]*Highway Statistics*, U.S. Department of Transportation, Washington, D.C., 1992.
[3]Miller, P., and J. Moffet (1993).
[4]Miller, T. R., K. A. Reinert, and B. E. Whiting. *Alternative Approaches to Accident Cost Concepts: State of the Art,* Report FHWA/RD-83/079, FHWA, U.S. Department of Transportation, 1984.

One shortcoming of the study is that its data were based on a per-victim basis, rather than on a per-accident basis; it is therefore unable to be incorporated into the benefit-cost analysis which is often based on a state's accident data. Rollins et al.[1] later converted the data into a per-accident form by using the numbers of fatalities and injuries per accident in five states. These figures are provided in Table 3.4.

Table 3.4 Costs of Accidents in Rural and Urban Area

	Fatal	Non-Fatal
Rural		
Direct	$34,695	$6,536
Indirect	$848,442	$4,108
Total	$883,317	$10,644
Urban		
Direct	$30,186	$5,755
Indirect	$796,670	$2,990
Total	$826,856	$8,745

Source: Rollins, J. B., and W. F. McFarland. "Costs of Motor Vehicle Accidents and Injuries," *Transportation Research Record 1068*, 1988.

The other important element useful in tracking accident costs is frequency of accidents. There are several databases that track annual accident counts. The National Accident Sampling System (NASS) is operated by the National Highway Traffic Safety Administration (NHTSA) and collects information on all police-reported crashes, including those that result in non-fatal injury and/or property damage. One part of the NASS is the General Estimates System (GES), which uses a randomly selected sample of reports, approximately 45,000 in size, from the annual police-reported crashes recorded by NASS. The GES develops estimates and forecasts of annual occurrences based on the probability sample selected. All the GES statistics presented are estimates, which can be used to trace accident trends and the state of traffic safety. One should be cautious when using GES data, because they are based solely on police-reported crashes. The counts are recorded only as estimates and the counts for property damage crashes may be underestimated.

According to the GES,[2] an estimated 6,110,000 accidents occurred in 1991. Of the total, an estimated 67 percent were property-damage-only crashes, 28 percent involved minor or moderate injuries, and 6 percent resulted in severe or fatal injuries. Passenger cars and light trucks, vans, and utility vehicles comprised an estimated 95 percent of all crash-involved vehicles. The estimated number of crashes by severity and number of crashes involving the various vehicle types are presented in Tables 3.5 and 3.6.

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[1]Rollins, J. B., and W. F. McFarland. "Costs of Motor Vehicle Accidents and Injuries," *Transportation Research Record 1068*, 1988.

[2]National Highway Traffic Safety Administration. *General Estimates System 1991*, U.S. Department of Transportation, Washington, D.C., 1993.

Table 3.5 Estimated Crashes by Severity, 1991

Crash Severity	Number	Percent
Property Damage Only	4,073,000	67
Minor or Moderate Injury	1,681,000	28
Severe or Fatal Injury	357,000	6

Source: National Highway Traffic Safety Administration. *General Estimates System 1991*, U.S. Department of Transportation, Washington, D.C., 1993.

Table 3.6 Estimated Crash-Involved Vehicles, 1991

Vehicle Type	Number	Percent
Passenger Car	7,710,000	72
Light Truck/Van/Utility Vehicle	2,475,000	23
Large Truck	330,000	3
Motorcycle	104,000	1
Bus	57,000	<1
Total	10,676,000	100

Source: National Highway Traffic Safety Administration. *General Estimates System 1991*, U.S. Department of Transportation, Washington, D.C., 1993.

A separate database concerning all fatal accidents is also maintained by NHTSA.[1] The Fatal Accident Reporting System (FARS) gathers data on the most severe traffic crashes that occur each year — those that result in loss of human life. Detailed descriptions are filed on each fatal accident. Characteristics of the crash are coded using over 90 different data elements that describe the vehicles and persons involved. Thus, FARS provides accurate information on the fatal vehicle accidents that occur each year. Table 3.7 summarizes the major findings of the FARS annual report and Table 3.8 presents data on the types of vehicles involved in fatal crashes.

Table 3.7 Fatal Accident Statistics, 1991

Fatal Crashes	36,895
Fatalities	41,462
Vehicles Involved	54,724
Fatalities per Fatal Crash	1.12
Vehicles per Fatal Crash	1.50

Source: National Highway Traffic Safety Administration. *Fatal Accident Reporting System 1991*, U.S. Department of Transportation, Washington, D.C., 1993.

[1]National Highway Traffic Safety Administration. *Fatal Accident Reporting System 1991*, U.S. Department of Transportation, Washington, D.C., 1993.

Table 3.8 Vehicles Involved in Fatal Crashes, 1991

Type of Vehicle	Number	Percent
Passenger Car	31,234	57.1
Light Truck	14,810	27.1
Large Truck	4,340	7.9
Buses	276	0.5
Motorcycle	2,832	5.2
Other	516	0.9
Unknown	716	1.3
Total	54,724	100.0

Source: National Highway Traffic Safety Administration. *Fatal Accident Reporting System 1991*, U.S. Department of Transportation, Washington, D.C., 1993.

Given that the total million vehicle miles traveled (million VMT) in 1991 was 2,172,214, the national rate of fatal crashes per 10 million VMT was 0.17, and the rate of fatalities per 10 million VMT was 0.19. Other types of accident rates are presented in Table 3.9.

Table 3.9 Accident Rates by Type, 1991 (per 10 million VMT)

Accident Type	Number	Rate
Property Damage Only	4,073,000	18.75
Minor or Moderate Injury	1,681,000	7.74
Severe	320,105	1.47
Fatal Crashes	36,895	0.17

Source: National Highway Traffic Safety Administration. *Fatal Accident Reporting System 1991*, U.S. Department of Transportation, Washington, D.C., 1993. National Highway Traffic Safety Administration. *General Estimates System 1991*, U.S. Department of Transportation, Washington, D.C., 1993. *Highway Statistics*, U.S. Department of Transportation, Washington, D.C., 1992.

It is necessary to point out the significant differences in accident injury and fatality rates between urban and rural roads, expressway and non-expressway facilities, auto/truck and other modes. To illustrate, the medium fatality, injury, and property-damage-only (PDO) accident rates by different modes in Boston and Portland[1] are listed in Table 3.10.

By using per-accident cost and accident rates, it is possible to calculate the total accident costs. However, some of the costs may overlap with the costs counted in other sections. The internal insurance premiums are covered by personal costs. The external costs of travel time delay resulting from accidents were discussed and included in the previous section. This section focuses on the other external costs not borne by drivers.

[1]Apogee Research Inc. (1994).

A recent study by Urban Institute[1] estimates that, in 1988, 14.8 million motor vehicle crashes cost $334 billion. The types of costs imposed by traffic vary widely, ranging from user costs paid by insurance companies, to societal costs paid by public assistance, to government costs. The largest cost category was pain, suffering, and lost quality of life — a total of $228 billion, estimated on the basis of the willingness of accident victims to pay to reduce the risks of such effects. The remaining $130 billion in losses was spread over productivity losses, property damage, medical expense, legal and court costs, administrative costs, workplace cost, travel delay, and emergency services. For the most part, these costs are covered through auto insurance paid for by drivers. The remaining costs are picked up by federal and state government. The details of these costs are summarized in Table 3.11.

Table 3.10 Medium Fatality, Injury and PDO Rates (per 10 million PMT)

	Expwy	Non-Expwy	Comm. Rail	Rail Transit	Bus	Bicycle	Walks
Boston							
Fatality	0.039	0.182	0.110	0.018	0	0.126	0.007
Injury	4.67	24.23	3.30	12.57	13.15	82.28	51.77
PDO	16.1	93.3	0	0	31.8	0	0
Portland							
Fatality	0.097	0.146	n/a	n/a	0	0.126	0.007
Injury	6.50	25.34	n/a	n/a	71.71	82.28	51.77
PDO	12.60	126.9	n/a	n/a	31.1	0	0

Source: Apogee Research Inc. *The Cost of Transportation: Final Report,* Prepared for Conservation Law Foundation, 1994.

Table 3.11 Cost of Motor Vehicle Accidents (Billions of 1988 dollars)

	Paid by Drivers Directly	Not Borne by Drivers
Productivity Loss	45.0	13.1
Property Damage	38.3	0.0
Medical	10.1	2.6
Legal	7.9	0.0
Administrative	7.8	0.0
Workplace Costs	2.4	0.0
Travel Delay	2.0	0.4
Emergency Service	0.9	0.0
Pain, Suffering, etc.	228.5	39.0
Total	358.5	55.2

Source: Urban Institute. *The Costs of Highway Crashes,* prepared for FHWA, Pub. No. FHWA-RD-91-055, 1991.

[1]Urban Institute. *The Costs of Highway Crashes,* prepared for FHWA, Pub. No. FHWA-RD-91-055, 1991.

As shown, the total cost of accidents not borne by users comes to approximately $55 billion per year, or 15.4 percent of the total accident costs. In its study, Apogee[1] reported the unit cost for different modes in the Boston and Portland areas. Since insurance premiums do not cover public service and damage to public property, do not pay the cost of travel time delay born by other travelers due to accidents, do not account for workplace and household productivity losses that result from injuries, pain and suffering, and lost quality of life for the victims and their families, the authors divided the accident cost — ranging from medical bills to lost wages to insurance overhead — into several responsibilities carried by more than one party. For example, medical bills are paid partly by accident victims (a user cost in our classification), partly by insurance companies (a societal cost), and partly by public assistance (a governmental cost). Table 3.12 presents the monetary responsibilities borne by all three parties — users, government, and society.

Table 3.12 Accident Cost by Responsibility (cents per PMT)

	Expwy	Non-Expwy	Comm. Rail	Rail Transit	Bus	Bicycle	Walks
Boston							
User	0.4–0.5	2.2–2.4	0.7	0.7	0.8	1.4	0.6
Government	0.2	0.8–1.0	0.3	0.3	0.3	0.5	0.2
Society	0.4–0.5	2.0–2.3	0.6	0.7	0.8	1.3	0.6
Portland							
User	0.6–1.0	2.0–2.7	n/a	n/a	3.2–3.7	1.4	0.6
Government	0.2–0.4	0.8–1.1	n/a	n/a	1.3–1.5	0.5	0.2
Society	0.5–0.9	1.9–2.6	n/a	n/a	3.4–3.9	1.3	0.6

Source: Apogee Research Inc. *The Cost of Transportation: Final Report*, Prepared for Conservation Law Foundation, 1994.

Regarding the external costs associated with accidents, the challenge is to realistically estimate the costs of loss and grief. The hedonic method used widely indicates that willingness to pay to avoid the loss of a loved one equals about 50 percent of an individual's willingness to pay to avoid his/her own death. Using $1.5 million per life, the psychological loss associated with the death of a car occupant in an auto accident thus equals about $0.75 million. The total externality associated with vehicle fatalities is about $33 billion per year, or $0.011 per PMT[2]. The same willingness-to-pay method can be applied to permanent, severe disablement, and for other severe injuries. The externality associated with severe injuries and disability to vehicle occupants is about $8 billion, or $0.0027 per PMT.[3] The external cost associated with less serious, non-permanently disabling injuries to vehicle occupants is about $38.5 billion, or $0.013 per PMT.[4]

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[1]Apogee Research Inc. (1994).
[2]Miller, P., and J. Moffet (1993).
[3]Miller, P., and J. Moffet (1993).
[4]Miller, P., and J. Moffet (1993).

In addition to the external costs associated with deaths and injuries to vehicle occupants, Miller and Moffet[1] have estimated the externalities associated with non-vehicle occupants. The estimate for loss and grief indicated that the total annual externality associated with death of non-occupants in accidents reaches $7.8 billion, or $0.0025 per PMT; that the cost associated with serious and permanent injuries of non-occupants is $1.8 billion per year, or $0.0006 per PMT; and that the external cost associated with non-permanent injuries of non-occupants is $8.9 billion annually, or $0.003 per PMT. Overall, the sum of the above external costs is about $98 billion per year, or $0.033 per PMT. This estimate is viewed as a conservative one. In the same report, the authors estimated that bus and rail accident costs are approximately $0.3 billion and $0.14 billion, or $0.007 per PMT and $0.006 per PMT, respectively.

3.3.5 Air Pollution

The social cost of air pollution is possibly one of the most important social costs of highway use. The byproducts of transportation contribute substantially to the nation's air quality problems. As shown in Table 3.13, the transportation sector is the leading contributor to carbon monoxide emissions (CO), and the second leading contributor for lead (Pb), nitrogen oxides (NO_x), hydrocarbons (HC) or volatile organic compounds (VOCs, a major contributor to smog), and particulate matter (PM-10). This trend continues despite tremendous efforts by automobile engineers to reduce vehicle emission rates over the last 10 years, as shown in Table 3.14.

Table 3.13 Percentage of Regulated Emission by Sector, 1992

Emission	Transportation	Fuel Combustion	Industrial Process	Solid Waste & Other
CO	80.2	7.1	5.7	7.0
Pb	30.6	9.7	45.4	14.3
NO_X	44.6	50.7	3.8	0.9
HC or VOCs	36.2	3.1	13.3	47.4
PM-10	30.9	18.5	32.7	17.9
SO_2	4.7	85.8	9.2	0.3

Source: Environmental Protection Agency. *National Air Quality and Emissions Trends Report, 1992*, EPA 454/R-93-031, Research Triangle Park, North Carolina, 1993.

In *America's Energy Choices*,[2] the authors reported that, in 1988, total emissions from all sources were 5.26 billion tons CO_2, 23.10 million tons SO_2, and 19.81 million tons NO_x, of which large amounts are generated by the transportation sector. The authors further estimate that the figures will continue growing for the next 10 years.

The three most important and recognized pollutants generated from motor vehicle use, CO, HC, and NO_x, are pollutants emitted directly into the atmosphere by vehicles. CO and HC result

[1]Miller, P., and J. Moffet (1993).
[2]*America's Energy Choices: Investing in a Strong Economy and a Clean Environment*, the Union of Concerned Scientists, MA, 1991.

from incomplete combustion of fuel during the operation of internal combustion engines. Evaporation of fuel also creates HC. NO_x is produced when oxygen and nitrogen in the air combine under heat and pressure during the internal combustion process.

Emission reduction efforts have been plagued by disagreements over the importance of air quality relative to the benefits of personal mobility and convenience. In the past, urban areas responded to congestion problems by building additional highway capacity. Now, under the Intermodal Surface Transportation and Efficiency Act (ISTEA) of 1991, surface transportation can no longer proceed without considering environmental impacts.

Table 3.14 Emission Rates (grams per mile), 1977 and 1985[1]

Mode	Year	CO	HC	NO_X	SO_X	PM
Light Duty Vehicles (G)	1977	53.10	7.58	3.77	0.13	0.47
	1985	15.44	2.72	1.75	0.13	0.29
Light Duty Trucks (G)	1977	68.05	12.16	4.79	0.18	0.47
	1985	31.61	5.90	3.93	0.18	0.33
Light Duty Vehicles (D)	All Years	1.70	0.46	1.60	0.54	0.73
Motorcycles	1977	28.00	5.66	0.25	0.03	0.189
	1985	27.65	7.18	0.26	0.03	0.19
Heavy Duty Vehicles (G)	1977	184.89	31.43	12.04	0.36	0.40
	1985	145.79	15.36	12.47	0.36	0.40
Heavy Duty Vehicles (D)	1977	28.70	4.60	20.90	2.80	1.30
	1985	28.70	4.60	20.90	2.80	1.30

Source: Haugaard, J. *Measures of Air Pollution Costs Attributable to Motor Vehicles*, Institute of Urban and Regional Research, Iowa City, IA, 1981.

Air pollution causes reduced visibility, reduced agricultural productivity, and even damage to human and other animal health. Vehicle exhaust causes tropospheric ozone, or smog, which is the product of interactions among NO_x, oxygen, and VOCs in the presence of sunlight. The health effects of pollutants from motor vehicles are summarized in Table 3.15.

The literature survey found a few studies attempting to update the air pollution costs of transportation. The studies are varied and based on particular pollutants, particular regions, and particular effects. The costs are quite significant, though they are highly uncertain and rarely comprehensive regarding the pollutants or types of costs counted.

Indeed, the quantification of pollution costs is complex and difficult. One approach, cited as control cost estimates, varies widely with the economic model used and with the assumptions made about the overall potential for efficiency improvements. The fundamental problem with control cost estimates is that they cannot simulate the damage caused by emissions. One example of such a simulation model is the Apogee[2] four-stage model, which is used to: (1) estimate the emissions of various pollutants in various locations; (2) estimate the ambient concentrations of

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[1]The emission rates for 1985 were determined by John Haugaard in 1981 using 1977 emission factors provided by the U.S. Environmental Protection Agency (EPA).

[2]Apogee Research Inc. (1994).

various pollutants that would result from the estimated emissions; (3) describe the health effects of these pollutants; and (4) evaluate the economic values of these health effects. Few studies followed these steps with specific information.

Table 3.15 Health Effects of Motor Vehicle Emissions

Pollutant	Health Effects
Carbon Monoxide	Interferes with absorption of oxygen by hemoglobin (red blood cells); impairs perception and thinking, slows reflexes, causes drowsiness, brings on angina, and can cause unconsciousness and death; it affects fetal growth in pregnant women and tissue development of young children.
Nitrogen Oxides	Can increase susceptibility to viral infections such as influenza; irritates the lungs and causes edema, bronchitis and pneumonia; and results in increased sensitivity to dust and pollen in asthmatics
Hydrocarbons or Volatile Organic Compounds	Low-molecular weight compounds cause unpleasant effects such as eye irritation, coughing and sneezing, drowsiness and symptoms akin to drunkenness; heavy molecular weight compounds may have carcinogenic or mutagenic effects. Some hydrocarbons have a close affinity for diesel particulates and may contribute to lung disease.
Sulfur Dioxide	Irritant, exacerbates asthma, bronchitis and emphysema; causes coughing and impaired lung functions.
Particulate Matter	Irritates mucous membranes and may initiate a variety of respiratory diseases; fine particles may cause cancer and exacerbate morbidity and mortality from respiratory dysfunction.

Source: Faiz, A., K. Sinha, M. Walsh, and A. Varma. *Automotive Air Pollution: Issues and Options for Developing Countries*, The World Bank, Washington, D.C., 1990.

DeLuchi et al.[1] estimated the total costs of air pollution, including the costs of mortality, morbidity, damage to vegetation and wildlife, damage to materials, and non-market costs of air pollution, as \$60–\$697 billion for the year 1985. Assuming transportation is responsible for 15–25 percent of this total, the authors estimated that \$9–\$174 billion could be attributed to transportation in 1985. The large range reflects the uncertainty surrounding the number of deaths and illnesses attributable to pollution, as well as the monetary value assigned to human health and life itself. The figure is composed mainly of the value of excess mortality, which was over 50 percent of the total damage costs. The authors further pointed out that about half of the air pollution damages are due to gasoline-powered passenger vehicles. Damage from diesel-fueled vehicles was on the order of 25 percent. Essentially all of this damage could be assigned to heavy diesel trucks.

In addition to the above costs resulting from pollution, DeLuchi used the hedonic price method to conclude that the benefit of improvement in visibility in Los Angeles was \$62–\$153 per household in 1979. Assuming that light extinction in 1985 was about 80 percent of the late 1970s level, the benefit of a 100 percent elimination of particulates, NO_x and SO_x, for the 1985 urban

[1]DeLuchi, M. A., D. Sperling, and R. A. Johnston. *A Comparative Analysis of Future Transportation Fuels*, Research Report, UCB-17S-RR-87-13, Institute of Transportation Studies, University of California, Berkeley, 1987.

population is about $52–$128 billion. If one-third of this is actually due to visibility alone, the costs are in the range of $17–$43 billion per year.

Transportation air pollution generates not only from the tailpipe, but from other sources, e.g., auto manufacturing, fuel production, gasoline distribution, pollution in petroleum recovery, refining and transmission, and oil spills. Some of the costs are very difficult to estimate. A rough estimation given by DeLuchi et al.[1] suggested damage costs of $0.65 billion to $3.4 billion. Overall, the total cost of pollution ranges from $26.65 billion to $220.4 billion per year.[2] As reported by Hanson,[3] other studies, including those by Ketchan and Komanoff and the American Lung Association, estimate that the total annual damage costs of pollution range from $1 billion to $50 billion. MacKenzie et al.[4] estimated the annual pollution damage to be $10 billion, in 1989 dollars, excluding the costs of acid rain, chronic health problems, carbon monoxide health impacts, and forest damage from low-altitude ozone. In addition, the authors estimated the external cost resulting from climate change. The original data were from a study by Dale Jorgenson of Harvard and Peter Wilcoxen of The University of Texas. They estimated that a phased-in tax on fossil fuels, reaching $60 per ton of carbon in the year 2020 would cut U.S. carbon dioxide emissions to 80 percent of the 1990 level by 2005. A $60 per ton tax translates to $0.20 a gallon, which eventually would cut the use of coal. This tax would cost motorists about $27 billion per year. In the NRDC report, Miller and Moffet[5] gave a comprehensive summary of economic costs associated with the environmental effects of various transportation modes. Their results, presented in Table 3.16, were derived primarily from the results of an extensive literature review and analysis based on the report by Pace University.[6]

Table 3.16 Air Pollution Costs by Mode

Mode	Cost ($ per PMT)	Annual Cost (Billion $)
Car	0.038–0.071	86–160
Light Truck	0.045–0.084	34–62
9-person Vanpool	0.010–0.018	0.0006–0.001
Bus (diesel)	0.016–0.045	0.6–1.6
Heavy Rail (diesel)	0.016–0.041	n/a
Heavy Rail (electric)	0.012–0.038	n/a
Light Rail (diesel)	0.023–0.076	0.16–0.50
Transit (electric)	0.021–0.062	0.25–0.75

Source: Miller, P., and J. Moffet. *The Price of Mobility — Uncovering the Hidden Costs of Transportation*, Natural Resources Defense Council, 1993.

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[1]DeLuchi, M. A., D. Sperling, and R. A. Johnston (1987).
[2]DeLuchi, M. A., D. Sperling, and R. A. Johnston (1987).
[3]Hanson, M. E. (1992).
[4]MacKenzie, J. J., R. C. Dower, and D. D. T. Chen (1992).
[5]Miller, P., and J. Moffet (1993).
[6]Ottinger, R., N. Robinson, S. Babb, D. Wooley, and D. Hodas (Pace University Center fro Environmental Legal Studies); S. Buchanen (environmental consultant); P. Chernick and E. Caverhill (PLC Inc.); A Krupnick, W. Harrington and S. Radin (Resources for the Future), and U. Fritsche (Oko Institute). *Environmental Costs of Electricity*, prepared for New York State Energy Research and Development Authority and U.S. Department of Energy, 1990.

It is worth noting that Miller and Moffet's figure[1] included the cost of global warming, which is mainly attributed to CO_2 emissions. About half of the costs listed in Table 3.16 are due to the damage of global warming. An additional study, the Federal Highway Administration's 1982 "Federal Highway Cost Allocation Study," estimated the unit cost of air pollution per auto vehicle mile traveled (VMT) to be $0.015, in 1980 dollars. Finally, a survey of fifteen studies conducted by Litman[2] in 1992 found that the cost per auto VMT for air pollution fell within a range of $0.010 to $0.072. Most studies of transportation pollution costs ignore visibility costs. Visibility is reduced primarily by sulfate and nitrate particles. Besides DeLuchi's study mentioned earlier, Hanson[3] estimated the costs of smog associated with automobile emissions to be $7.9 billion in 1983, which is significantly different from the figures given by DeLuchi et al.[4] These estimates are very high and somewhat controversial. It is important to differentiate between urban and rural air pollution costs. The effects of air pollution's costs per capita and per PMT could be higher in urban areas than the national average because of the type of driving, geography, population density, and other factors. The same quantity of emissions will have a different effect in southern California than in other parts of the U.S. In addition, costs may not linearly relate to total emissions. Thus, the marginal impact of auto emissions in an urban area may be higher than the marginal impact of the same emissions in a rural area. An important consideration to note is that as the average speed increases, the vehicle emission rate per-mile decreases. Based on this observation, there is an argument that additional roads will reduce congestion and lead to higher average speeds, thus, in turn, reduce emissions. However, the argument is problematic because it ignores the significant feedback from new roads.

3.3.6 Energy

The U.S. is the world's largest consumer of petroleum. Since 1973, all other sectors of the U.S. economy have been reducing their consumption of petroleum, while the transportation sector's consumption has been increasing, as shown in Table 3.17.

Table 3.17 U.S. Oil Consumption by Sector (quadrillion Btu)

	1973	1990	% Change
Residential & Commercial	4.39	2.50	-43
Industrial	9.10	8.49	-7
Utility	3.52	1.25	-64
Transportation	17.83	21.41	20

Source: Transportation Energy Data Book: Edition 12, 1992

[1]Miller, P., and J. Moffet (1993).
[2]Todd Litman. Transportation Cost Survey. As cited in Patrick DeCorla-Souza and R. Jensen-Fisher. "Comparing Multi-modal Alternative in Major Travel Corridors", Presented at the 73rd Annual Meeting of the Transportation Research Board, Washington, D.C., 1994.
[3]Hanson, M. E. (1992).
[4]DeLuchi, M. A., D. Sperling, and R. A. Johnston (1987).

The transportation sector is currently the largest consumer of petroleum. Despite fuel efficiency increases over the last two decades, transportation fuel consumption has increased 2.6 percent each year since 1980. It is predicted that the improvement in fuel efficiency from improved combustion technology will be more than offset by increased VMT growth, growth of the light truck and van fleet, and more congested urban travel.

The gas price includes the direct energy cost, which has been included in personal use cost, and the federal and state fuel tax, which is part of the capital and non-capital cost. However, as Miller and Moffet assert, [1] "money spent at the gas pump does not cover many of the externalities associated with oil production and use." Several types of external costs include direct subsidies and tax write-offs provided to the oil industry, macroeconomic impacts of oil import dependence, and the cost of energy security, including the cost of financing and maintaining a strategic petroleum reserve and a military presence in the Middle East. Other related external costs, such as air pollution, water pollution, and green-house gas emissions resulting from the combustion of gas, have been or will be considered in other separate sections of this report.

In general, subsidies may be classified as loans with a below-market interest rate, special treatment to foreign operators, exemptions or exempt bonding, expensing of certain kinds of interest, and special deductions, allowances, or credits. It is unlikely that any of these subsidies will be available to future producers of alternative fuels. Miller and Moffet[2] estimate that indirect costs of oil industry subsidies for automobile energy use total $4 billion in annual federal tax subsidies, which equates to $0.0013 per PMT. This includes the subsidies to the interest charged for oil industry construction, tax benefits provided to foreign oil operations, and the exemptions of fuel sales tax in some states. The purpose of these subsidies is to maintain the current market price of the fuels.

In addition to these direct costs, the automobile's oil dependence imposes costs related to energy security — the result of uncertainty and instability in world energy markets. These security costs include expenditures for a strategic petroleum reserve, military expenditures to protect the Middle East region, and national income losses resulting from the contraction of demand for U.S. produced goods and services. One could argue that nothing would change if oil imports ceased, that the same Middle East activities would continue. However, it is obvious that the activities of the U.S. Sixth Fleet, as well as those of the U.S. rapid deployment force, are, to a large degree, directed at the oil-exporting countries of the Middle East. Had the U.S. and its allies been less dependent on imported oil, they would have much less interest in policing, protecting, bargaining with, and coercing the exporting nations. Accordingly, a portion of manpower and hardware resources now involved in Middle East activities would be assigned to other tasks. The value of these tasks is the opportunity cost of the current use of the resources in Middle East defense activities. Unfortunately, it is difficult to estimate the relevant labor and hardware resources of this

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[1]Miller, P., and J. Moffet (1993).
[2]Miller, P., and J. Moffet (1993).

external cost. MacKenzie et al.[1] attributed half of the entire amount of $50.5 billion to the strategic petroleum reserve and military expenditures, since motor vehicles account for half of U.S. oil consumption. This estimate may be high and further analysis may produce a more appropriate value. The total costs resulting from a strategic petroleum reserve, military expenditures to protect the Middle East region, and losses of the national income from contraction of demand for U.S. produced goods and services may exceed $0.014 per PMT,[2] on a unit basis.

Dependence on foreign oil also poses the problem of a possible sudden supply shortfall, including reduction in output because less oil is consumed, balance of trade problems, and the inability of non-oil markets to adjust efficiently to the price shock. The private sector can be expected to be able to minimize the first two kinds of potential losses beforehand. Investors, however, do not have an incentive to reduce the third kind of cost. The dual-fuel capability for reducing vulnerability of oil dependence does not exist in the transportation sector.

Potential disruption costs should be expressed as the expected annual value of the external costs of a sudden future price increase. As reported by DeLuchi et al.,[3] the estimate modeled by many researchers following the 1970s oil crisis ranged from $100 billion to $400 billion a year. These figures are extremely high. The cost of future supply disruptions could be as low as zero, since it is not completely unreasonable to assume that no disruptions will occur in the next century. Even if there is a disruption, the U.S. is currently prepared to deal with sudden shortfalls more effectively than it was in the 1970s. Furthermore, foreign sources of oil are more diversified now than they were in the 1970s.

A large component of the cost of oil is the transfer of wealth from U.S. oil consumers to Middle East oil producers. To maintain a trade balance in the face of increasing imported oil, either an increase in U.S. export earnings or a decrease in U.S. import expenses on non-oil products would be required. As a result, the dollar exchange rate would adjust to make U.S. exports more competitive and imports more expensive for U.S. consumers.

The absence of transportation alternatives in this auto-based transportation system could cause substantial economic losses in the U.S. through oil price volatility. The NRDC report estimated the maximum of these costs to be approximately $0.035 per PMT.[4] It is impossible to estimate precisely the amount of economic costs attributed to oil importation. The overall estimated figure ranges from $45 billion to $150 billion per year, or $0.015 per PMT to $0.05 per PMT.[5] Miller and Moffet[6] estimate that transit and intercity buses consumed 719 million gallons of gasoline and diesel in 1989. Based on the procedure used for automobiles and light trucks above, the estimated external social cost ranges from $374 million to $1,230 million per year, or $0.0085 per PMT to $0.028 per PMT. In the same report, it is estimated that the annual societal costs of

[1]MacKenzie, J. J., R. C. Dower, and D. D. T. Chen (1992).
[2]Miller, P., and J. Moffet (1993).
[3]DeLuchi, M. A., D. Sperling, and R. A. Johnston (1987).
[4]Miller, P., and J. Moffet (1993).
[5]Miller, P., and J. Moffet (1993).
[6]Miller, P., and J. Moffet (1993).

rail energy use, including both diesel and electricity rail service, total $100 million to $330 million, or $0.0039 per PMT to $0.013 per PMT.

3.3.7 Noise

Noise is often overlooked and rarely considered in transportation planning, except in the cases of airport or railway design. For highway passenger modes such as personal automobiles, buses, and motorcycles, the noise produced can be considered pollution imposed on the public. Thus, it is important to include the cost of noise in the total external costs of transportation for urban areas.

The effects of noise can be significant to human health. High noise levels can cause loss of permanent or temporary hearing, affect concentration and productivity, increase tension, impair health, and even lead to a heart attack. There is no precise noise threshold for annoyance — it varies with the time and location. A 50 dBA outdoor noise level in the daytime can have no detrimental effect, while the same level of noise at night may cause loss of sleep. Noise pollution in urban areas is caused by a multitude of sources. A survey conducted in 1971 confirmed that the major sources of outdoor noise in urban residential areas are motor vehicles, aircraft, and voices. The results of that survey are presented in Table 3.18.

Table 3.18 Noise Pollution Contribution by Source

Source	Percentage
Motor Vehicles	55
Aircraft	15
Voices	12
Radio and TV Sets	2
Home Repair Equipment	2
Construction	1
Industrial	1
Other Noises	6
Not Ascertained	8

Source: Bolt Beranek and Newman, Inc. *Survey of Annoyance from Motor Vehicle Noise*, Automobile Manufacturers Association, Inc., Report 2112, 1971.

The noise generated from transportation, including friction of tires, engine exhaust, engine operation, and brake friction, is a major source of unwanted urban noise. The regulations enacted by the Department of Transportation and the EPA provide minimal protection — they offer no more than guidelines and funding assistance for noise mitigation measures for highway projects. Although noise standards have been set for various vehicles, this only eliminates a small portion of vehicle noise, since engine exhaust usually accounts for only 10–15 percent of overall vehicle noise.

It is difficult to assess the costs of road noise, partly because of its pervasive and subjective nature and partly because of the difficulty in using traditional valuation techniques. Several literature sources on noise costs address the damage costs from loss of productivity, health care costs due to physiological effects, and reduced property values. The first measure is the "willingness to pay" principle. Costs are allocated according to studies of what people are willing to pay as a means of reducing the distracting and irritating effects of noise. In the case of property values, houses are considered less desirable if located next to or near a major source of noise. Therefore, the cost of noise on property values can be determined by comparing similar properties located in areas of different noise level exposure. In fact, a significant portion of the difference in property values can be assumed to be the cost of noise. MacKenzie[1] estimated the total cost of vehicular noise in urban settings to be approximately $9 billion per year (1989 dollars), with trucks causing 85 percent of this damage. The Federal Highway Administration's 1982 "Federal Highway Cost Allocation Study" estimated the unit cost of noise pollution per auto VMT to be $0.001 (1980 dollars). Miller and Moffet[2] reported that automobiles were responsible for the cost of $0.002 per VMT. Finally, KPMG calculated the proportionate value of the property affected by noise, and discounted the loss to estimate an annual value at about $0.008 per VMT[3] in Vancouver.

Another approach is the estimation of control costs. Transportation noise can be attenuated in three ways: on-vehicle control, barriers, and building insulation. The first one is recognized as the most cost-effective way of reducing noise, since barriers may magnify on-road noise if improperly designed.

The previous estimates by Miller and Moffet[4] of noise costs range from $0.0014 per PMT to $0.0023 per PMT, depending on the location of the sites. In their report, Apogee[5] indicated that the cost of noise varies directly with the number of people who hear it, so that the cost of automobile noise depends on the population density along its route. Estimated noise costs in Boston and Portland are listed in Table 3.19. The problem with these estimations is that they focus only on specific highway segments and conditions. There were no reported attempts to derive urban-wide values.

Table 3.19. Medium Auto Noise Cost (cents per PMT)

	Expwy	Non-Expwy	Comm. Rail	Rail Transit	Bus
Boston	0.1–0.2	0.1	0.1–0.3	0.3–0.4	0.2–0.5
Portland	0.1	<0.1	n/a	n/a	0.2

Source: Apogee Research Inc. *The Cost of Transportation: Final Report*, Prepared for Conservation Law Foundation, 1994.

Because buses are louder than autos, adding buses to roadways increases the noise impact. The overall effect depends on the locations of cars and frequency of buses. Since buses carry more passengers than automobiles do, the unit noise cost by bus is lower than its auto counterpart,

[1]MacKenzie, J. J., R. C. Dower, and D. D. T. Chen (1992).
[2]Miller, P., and J. Moffet (1993).
[3]KPMG (1993).
[4]Miller, P., and J. Moffet (1993).
[5]Apogee Research Inc. (1994).

ranging from $0.0005 per PMT to $0.001 per PMT.[1] Rail noise is highly dependent on the system's technology. Accounting for rail ridership, Miller and Moffet[2] estimated rail noise costs to be $0.0016 per PMT.

3.3.8 Building Damage

As with noise, damages caused by vibration in homes and business buildings along highways are rarely acknowledged as an effect of motor vehicle driving. When heavy trucks hit potholes, they can shake nearby buildings and cause damage, the cost of which transfers to the building owner. Assuming the cost of vibration damage to be one half of the total structural maintenance costs for buildings in urban areas, Ketcham[3] estimated the national loss due to vibration to be about $6.0 billion, of which transportation is responsible for $0.33 billion, or about $0.0001 per PMT.[4] There is no literature on building damage costs caused by bus and rail.

3.3.9 Water Pollution

Transportation is also a major contributor to water pollution. Water pollution can occur as a result of asbestos, lead, particulates (such as rubber deposits), road salts and other de-icing chemicals, discarded engine coolant, petroleum residuals (including leaks from lubrication points), and other detergents washing off roadways. Acid rain caused by vehicular emissions and leaking underground fuel tanks also contributes pollution to water sources.

In urban areas, the primary concern of water pollution is runoff after rainstorms. Runoff from transportation facility construction can produce very high phosphorus loading in surface water, reducing oxygen content and causing entrophication. Nitrogen oxides from tailpipe and smokestack emissions can also increase the nitrogen concentration in surface water. In addition, typical urban street runoff contains many pollutants, including solids and toxic substances like zinc, mercury, oil, and grease.

Salt and other de-icing substances are major contributors to transportation water pollution. They cause crop damage, loss of fish and wildlife, and some of the same health damages that air pollution causes. Miller and Moffet[5] estimate that the annual water pollution cost of de-icing is about $1.9 billion. Their estimate came from a study in Vermont, which cited that the annual cost of damage to vegetation from de-icing is about $0.65 billion nationwide, while additional cost is around $1.25 billion per year. Leaking underground storage tanks represent another source of water pollution, with their annual clean-up costing about $0.6 billion. (This estimate, however, is uncertain in that the clean-up may not eliminate the problem totally, meaning that there will ultimately be residual damage costs passed on to future generations.)

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[1]Miller, P., and J. Moffet (1993).
[2]Miller, P., and J. Moffet (1993).
[3]Brian Ketcham. "Making Transportation Choices Based on Real Costs", Transportation 2000 Conference "Making Transportation a National Priority." As cited in J. J. MacKenzie, R. C. Dower, and D. D. T. Chen. *The Going Rate: What It Really Costs to Drive*, World Resource Institute, 1992.
[4]Miller, P., and J. Moffet (1993).
[5]Miller, P., and J. Moffet (1993).

The total economic cost of oil spills has been estimated as \$30–\$300 million.[1] This estimate includes the opportunity cost of labor and resources used to clean-up spills, the welfare difference between a tourist's choice vacation spots, the decline in productivity of the fish industry, and the value of non-commercial wildlife. However, not all of this economic cost is external to the price of transportation fuels. As pointed out by the authors, industry bears about half the total economic cost related to non-market damages and liability of oil-spill defendants. This leaves the external cost of oil spills on the order of \$15–\$150 million per year. Based on a study by the U.S. government in 1979, it is estimated that oil clean-up costs for passenger vehicles are at least \$200 million per year, which equals about 40 percent of all petroleum clean-ups in a year.[2]

Other external costs resulting from cleaning up solids, chemicals, grease, and other contaminants, are difficult to estimate. Miller and Moffet[3] assume the figure to be around \$1.1 billion annually. By adding up all the costs described above, total water pollution costs equal about \$3.8 billion per year, or \$0.0013 per PMT. This figure is very close to that estimated by KPMG,[4] of \$0.001 per VMT or \$0.0016 per PMT.[5] The water pollution costs for buses and rail are not reported in the literature.

3.3.10 Wetlands

Wetlands serve important ecological functions, including water quality improvement, food and habitat sources, and flood-peak reduction. The construction of roadways and bridges and urban development cause serious problems to wetlands. About 10,117 hectares (25,000 acres) of wetlands continue to be lost each year in order to dispose of material excavated from transportation sites. Although this losing trend started declining recently, inland fresh water wetlands are not well protected from drainage, excavation, and cleaning. Unfortunately, the reviewed literature provides no economic estimates of the social cost of wetlands loss from transportation sources (beyond qualitative treatments).

3.3.11 Land Loss

The literature review found few studies presenting systematic economic estimates of land loss costs related to automobiles. Roads occupy approximately 2 percent of the nation's total land area, an area equal to 10 percent of the nation's arable land. Miller and Moffet[6] provide a useful discussion of urban land loss, citing that 202,345 hectares (500,000 acres) of arable land is lost to new roads each year. In some cases transportation infrastructure causes the extra loss of land — some of the roadway right of way is considered to be superfluous, resulting from more than an optimal amount of land being dedicated to road use. Theoretically it is possible to estimate the surplus mileage on the basis of a cost-benefit analysis. A stretch of road would be considered

[1]DeLuchi, M. A., D. Sperling, and R. A. Johnston (1987).
[2]Miller, P., and J. Moffet (1993).
[3]Miller, P., and J. Moffet (1993).
[4]KPMG (1993).
[5]Assuming average vehicle occupancy at 1.6 passengers per vehicle.
[6]Miller, P., and J. Moffet (1993).

surplus if the benefits received from it are less than the construction and maintenance costs. If the full societal costs of the land's conversion were paid by construction and maintenance of the road, then the society would be compensated for the conversion. There have been few research attempts to identify these surplus roads.

As cited in the Apogee study[1], Ketcham and Kommoff estimated that motor vehicles cause land losses amounting to $66.1 billion annually. This figure is problematic because of some assumptions made by the authors — for instance, that a third of all urban land area is devoted to streets, and one-half of the street can be eliminated for other purposes. This quantitative estimation, however, was the only one found in the literature review.

Other than the opportunity cost of the land consumed by transportation infrastructure described above, there are costs incurred from land sprawl — low-density, dispersed land development patterns. The KPMG study defined urban sprawl as "increased infrastructure costs resulting from low density land use patterns caused by an automobile-oriented transportation system."[2] The authors argued that low-density residential development increases the per capita municipal costs of roads, utilities, school transportation, and stormwater management. This cost has rarely been studied, though many researchers argue that there are large costs imposed on society by this type of development pattern.

The low-density development pattern could not have occurred without the development of the automobile. And it is predicted that if auto use remains inexpensive and accessible, the urban sprawl will continue to characterize U.S. urban growth patterns. Currently, less than 10 percent of the total population works in central business districts. Suburbs provide locations for both work and residences. The controversial question behind urban sprawl is whether transit can accommodate the travel demand of suburban residents and workers. As current fixed-route transit is used primarily by those who work or live in central business districts, continued and inevitable urban sprawl appears to require building more roads. Nonetheless, evidence from Canadian and European cities indicates that in many cases flexible and responsive transit service and suburban development can be compatible.

The hidden costs behind urban sprawl include expenditures for such public services as water and sewage, education, and roadway construction; the decline of urban environmental quality is another hidden cost. Although transportation plays a significant role in the density and dispersion of land development patterns, there are few studies that effectively quantify the relative contribution of transportation to this type of development pattern. It is also somewhat difficult to separate the effects of transportation on land use from the impacts of other causes of sprawl (such as zoning). A rough estimate of urban sprawl is about $0.009 per VMT.[3]

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[1]Apogee Research Inc. (1994).
[2]KPMG. (1993).
[3]KPMG (1993).

3.3.12 Loss of Aesthetics

In addition to the damage cause by pollution, there is the cost of the aesthetic damage of transportation itself. Loss of aesthetic value results from the alteration and influence of highways on urban and rural landscapes, and from visibility losses attributable to motor vehicle emissions. While there are qualitative discussions of aesthetic loss, there are few attempts to place an economic value on it. As cited in the Apogee study,[1] the aesthetic loss costs $600 million along a three-quarter mile downtown road in Boston. Such approaches are controversial. Hanson[2] does mention that aesthetic cost would not seem to be a high priority for work focused on establishing urban tolls.

3.3.13 Loss of Property Values

A new traffic artery usually has a negative impact on adjacent land, unless other economic factors favoring economic growth are present. The expansion of roadways, which can lead to increased noise and visual intrusion, can considerably alter property value. On the other hand, the accessed region has a higher property value. Rail transit and road developments have similar qualitative impacts on property values, through their actual impact can differ significantly. Construction of a major rapid transit system can substantially impact the location of new commercial development, which most likely will arise around transit stations. There is no research attempting to quantify the external cost resulting from loss of property values.

3.3.14 Transportation Equity

An auto-centric society such as ours can ultimately affect the poor, the handicapped, the elderly, children, and other groups that have limited access to autos. In addition, the poor are those most likely to be displaced by highway and parking construction. The elderly and the physically weak suffer the most from pollution. To address these issues, equity in transportation planning is defined as: equality, distribution according to need, and user pay. Miller and Moffet[3] argue that equality is neither politically realistic nor necessarily required. In general, the aged have lower demand for commuting. Need is hard to measure. It is not clear what system would be appropriate to satisfy any given demand. User pay is also problematic. Imposing marginal user costs could lead to the potential inequitable distributional effects of a user-pay policy. The poor would reduce their demand tremendously, since the proportion of household expenditures required to pay for driving is proportionally higher than average for the poor.

Various estimates have been made of the total number of people disadvantaged by the auto-based transportation system in the U.S. The estimates vary widely, depending on the definition of *disadvantaged.* Unfortunately, no quantitative estimate was found in this literature review.

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[1]Apogee Research Inc. (1994).
[2]Hanson, M. E. (1992).
[3]Miller, P., and J. Moffet (1993).

3.4 SUMMARY

Full-cost transportation analysis attempts to include all of the costs associated with each transportation mode. This section has summarized the various social or external costs of transportation that are often ignored in cost evaluations of transportation alternatives. These various cost components have been integrated into a new full-cost transportation model that is introduced in the next chapter.

CHAPTER 4. A NEW EVALUATION TOOL: MODECOST

4.1 INTRODUCTION

This report addresses the dilemma of the transportation planning community with regard to the evaluation and comparison of urban passenger transportation modes. Chapter 2 documented this need, introduced the full-cost approach as a likely candidate for meeting this need, and reviewed the literature addressing this topic. In addition, Chapter 2 discussed two critical issues — the consideration of benefits with regard to transportation alternatives, and the issue of transfer of funds versus societal gain. Finally, Chapter 3 provided background into the valuation and identification of transportation cost components.

This chapter introduces a full-cost transportation model developed by the research team for analyzing modal alternatives for transportation corridors. The software, termed MODECOST, calculates the full costs of a transportation alternative based upon various demand inputs.

4.2 GENERAL DESCRIPTION OF MODECOST

In the development of MODECOST, the CTR project team paid deliberate attention to issues that were brought up in Chapter 2. These issues include the close relationship of full-cost accountability to travel demand modeling, the measurement of transportation "benefits," handling of transfer payments, and the determination of costs for certain non-market costs.

As a full-cost model, MODECOST attempts to calculate the total life-cycle costs for private vehicle use, bus, and rail modes along a particular corridor for a given community. Under each mode, the costs are grouped into roadway facility, external, and personal vehicle costs; the model calculates subset costs for each of these groups. Full-cost models such as MODECOST incorporate aspects of modal costs that have not traditionally been quantified in planning and decision matrices. Many of the cost components have been proposed in previous work on benefit-cost and full-cost analysis; some have even been employed in models proposed by DeCorla-Souza and by Jensen-Fisher. MODECOST employs a user-friendly Windows environment, offers flexibility with regard to modes and scenarios, and provides straightforward output that can greatly facilitate exploration and experimentation.

Perhaps the greatest benefit of MODECOST (but also its biggest drawback) is the flexibility it offers with regard to inputs. Although default values are provided on the basis of research conducted by the CTR project team, the user has ultimate control over the value of inputs to the MODECOST model. The benefit to this approach is that, for example, it enables a user/community to value travel time at a greater or lesser value than the default provided. Other values that are particularly dependent on the individual community include the discount rate, the values of pollution costs (air, water, and noise), and the value of right of way. The next section discusses possible MODECOST input types, which, again, require input values that are dependent on the user.

4.3 MODECOST COST COMPONENTS

For each mode — auto, bus transit, and rail transit — costs are grouped into agency, external, and personal user costs; the model calculates subset costs for each of these groups, as shown in Figures 4.1, 4.2, and 4.3. The agency cost is calculated on the basis of both capital and non-capital costs to the agency (usually governmental but occasionally private) responsible for the facility. In the case of roadway facilities under the private vehicle and bus transit modes, capital costs include the expense of right-of-way acquisition, construction, and rehabilitation of roadway facilities (the share of cost attributable to each mode is weighted by axle-loadings and vehicle-miles traveled by each on the facility). For bus transit, capital expenses include the buses, transit center, park-and-ride lots, and bus-stop shelters. Likewise, rail capital expenses include vehicle, guideway, station, yard, and right-of way costs. Agency non-capital costs are included as well for each mode — the costs of routine maintenance, administration and safety, and debt service, if applicable. These non-capital costs (and even the ultimate necessity of rehabilitating the facility) may not always be considered in traditional assessments of the need for a new facility, yet clearly these costs add up over time.

External costs of different modes of transportation have received more attention over past decades as awareness of environmental impacts of transportation has increased. The MODECOST model includes air quality as the primary environmental impact under its own category. External costs, such as incident delay and accident costs, are also calculated. In the "Other" category, such costs as energy security, water pollution, land loss, noise, weather change, and aesthetics costs are represented. Because these additional costs can vary significantly between modes, their inclusion in the decision-making process is required to address the efficiency and safety of different modes within a particular corridor.

The last group of costs to be calculated for each mode is the cost to the private user. For the private vehicle mode, this is the driver and any passengers; for bus and rail transit, this person is the passenger. For the private vehicle mode, the user cost includes the expense of ownership and operation of the vehicle, in addition to travel time cost. For the bus and rail transit modes, the private user expense is limited to travel time cost (fares, like tolls for private vehicle users, are excluded because they represent transfers from user to agency and not a transportation cost).

4.4 LIFE-CYCLE ACCOUNTING IN MODECOST

The calculation of costs on a life-cycle basis is a significant component of the MODECOST model. First, because most transportation structures operate over a long period of time, their often substantial initial costs should be allocated over their expected lifetime, rather than in one lump sum at their inception. In addition, life-cycle costing takes into account other costs that accrue throughout the life of a structure, such as maintenance, operation costs, user costs, and external costs. In general, the life-cycle cost approach involves both the acquisition and operation stages. This aspect of the MODECOST model is discussed in more detail in CTR Research Report 1356-2.

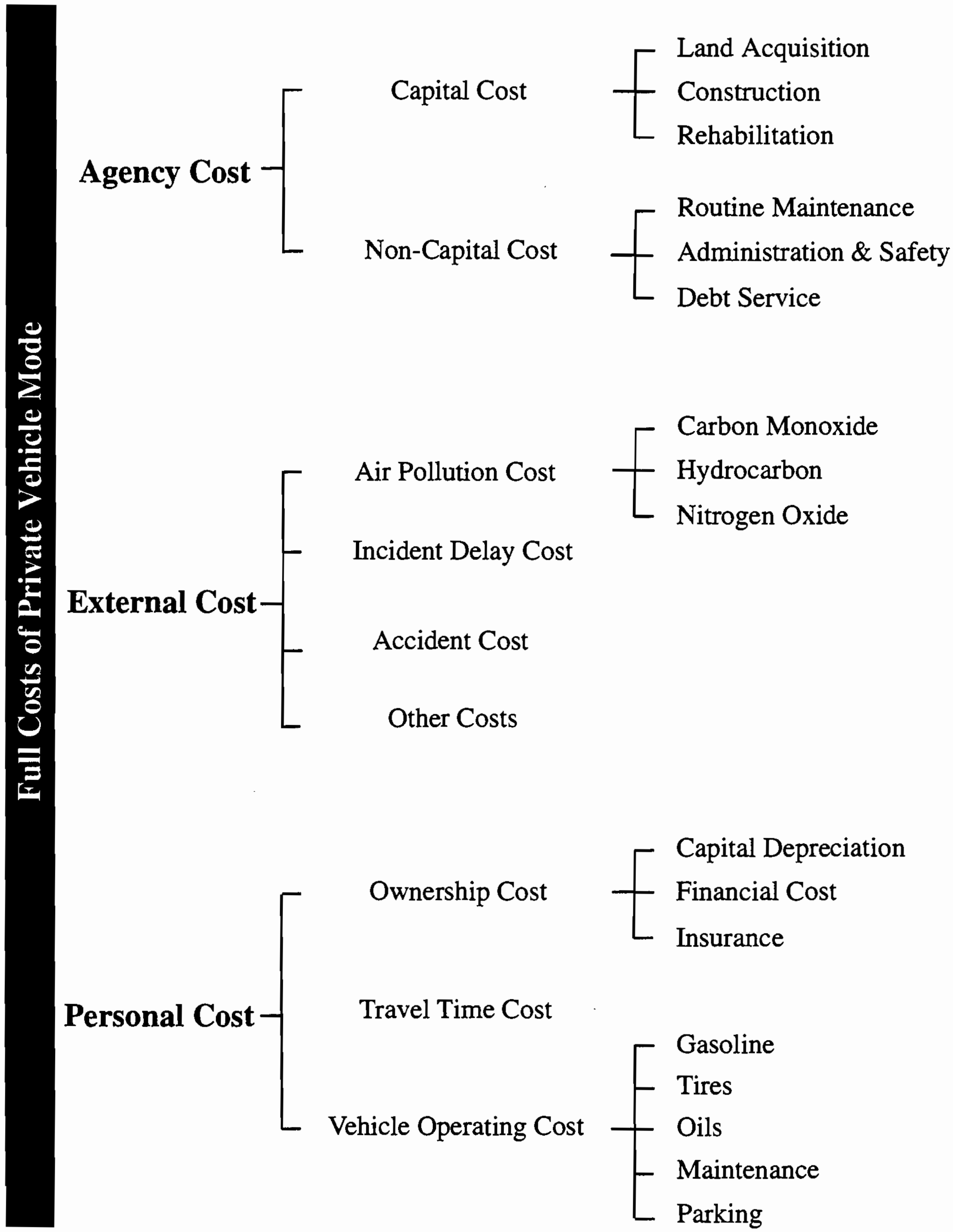

Figure 4.1 Cost Elements of the Private Vehicle/Roadway Mode

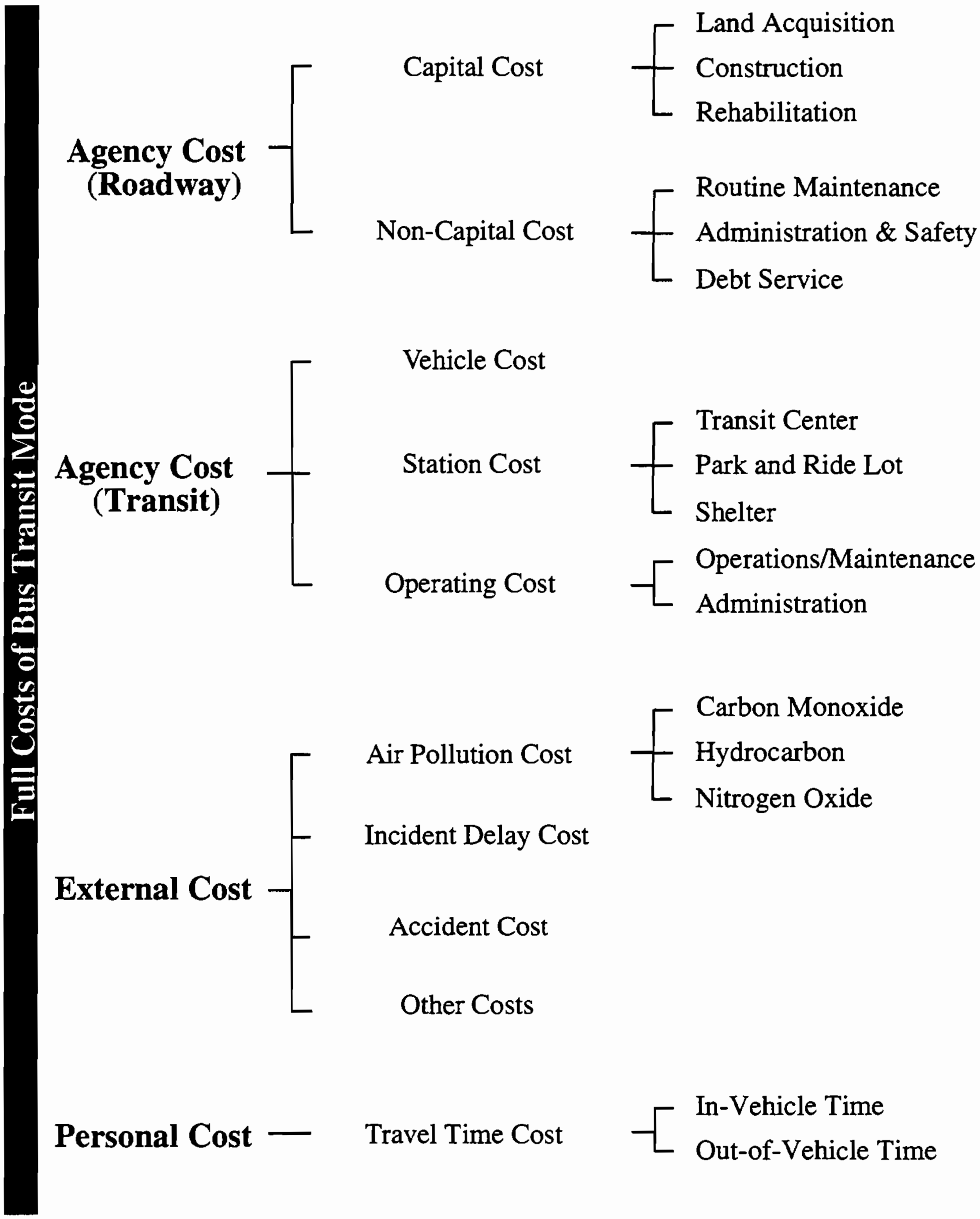

Figure 4.2 Cost Elements of the Bus Mode

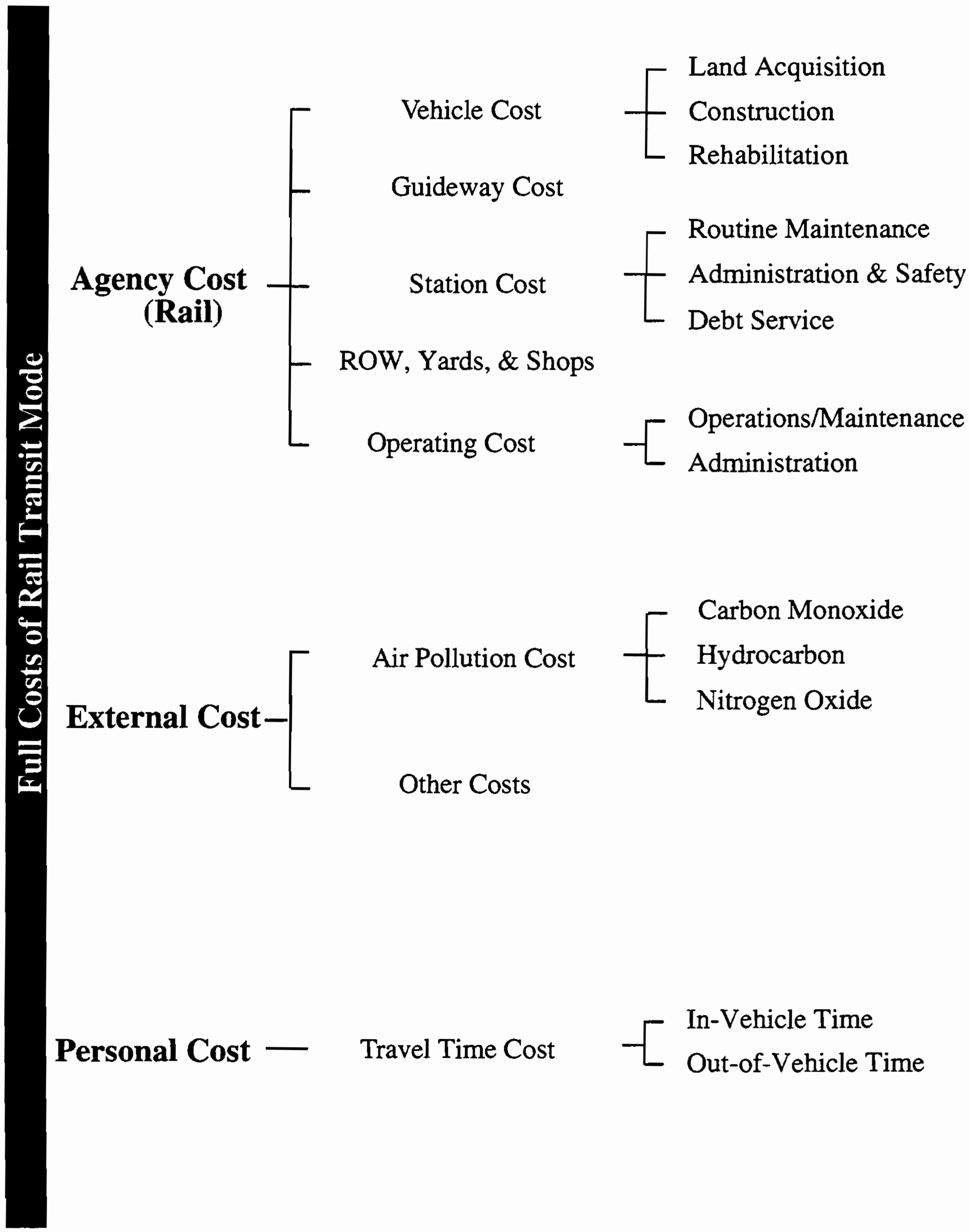

Figure 4.3 Cost Elements of the Rail Mode

CHAPTER 5. CONCLUSION

Expenditures for U.S. public passenger transportation total $1.2 to $1.6 trillion each year, a figure roughly equal to one-quarter of the annual GNP. Automobile transportation is responsible for nearly all of these costs. The direct personal costs of automobile travel account for about 15 to 20 percent of the GNP.[1] The external cost of automobile transportation reaches $380 to $660 billion per year. This poses a new challenge to transportation planners and decision makers. In the past, transportation investment decisions were based on mobility. These decision approaches, however, may not be efficient in terms of total costs to society. This challenges us to develop a new approach to help determine the most efficient transportation investment alternatives.

The concept of full-cost analysis of transportation is a more realistic approach for use in transportation planning and investment decisions, insofar as it considers the effect of transportation on society and the environment. The full-cost approach examines transportation modes on the basis of their combined costs: facility costs imposed on agencies, external costs imposed on society, and private costs imposed on users. Currently, users are directly paying the private costs, which include the owning and operating costs of vehicles. Users also pay transportation taxes and fees, of which a portion is used to support transportation expenses. However, vehicle owners pay no direct charges for the damage they collectively impose on the environment and on society.

A full-cost analysis approach can eliminate these inconsistencies and inequities in assigning responsibility for the costs of transportation. It provides for a more accurate approach to future transportation investment because it broadens our understanding of the total costs each mode of transportation imposes on society. Also, full-cost analysis serves as a basis for evaluating the total cost of each transportation mode, and for identifying the major costs paid by users and those costs that are subsidized by society. This report has reviewed the circumstances that have prompted a need for a more coordinated multimodal urban transportation system.

Both the Intermodal Surface Transportation Efficiency Act of 1991 and the Clean Air Act Amendments of 1990 are encouraging the development of a better, more efficient, and more environmentally sensitive transportation system. The implementation of a multimodal urban transportation system requires the use of a full-cost analysis approach to evaluate each transportation mode. Importantly, in order to receive the maximum benefit from full-cost analysis, a method for properly charging the external costs must be developed. Table 5.1 summarizes all the external costs and infrastructure and vehicle ownership costs presented in this report. The total costs for auto, bus, and rail are estimated to be $0.38 to $0.52 per PMT, 0.35 to $0.40 per PMT, and $0.48 to $0.52 per passenger mile of travel (PMT), respectively.[2] The costs represent national averages, so that actual costs for specific times and routes may be considerably higher or lower. In

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[1]Miller, P., and J. Moffet. *The Price of Mobility — Uncovering the Hidden Costs of Transportation*, Natural Resources Defense Council, 1993.

[2]The figures are derived by summing all the cost elements for each of three modes quantified by P. Miller and J. Moffet (1993).

addition, these estimates do not account for differences in benefits provided across transportation modes and at different times on different routes.

As shown in Figure 5.1, a considerable amount of the cost of each mode is subsidized rather than paid directly by users. Automobile users receive about 85 percent of their subsidy in the form of external costs, such as air pollution, parking, and accidents. On the other hand, bus and rail operators receive their subsidy primarily in the form of government expenditures. This difference helps to explain the (incorrect) perception that, in general, transit is more heavily subsidized than automobile travel. The subsidies that transit receives are easily scrutinized while the subsidies that automobiles receive are hidden, not easily quantified, and widely dispersed.

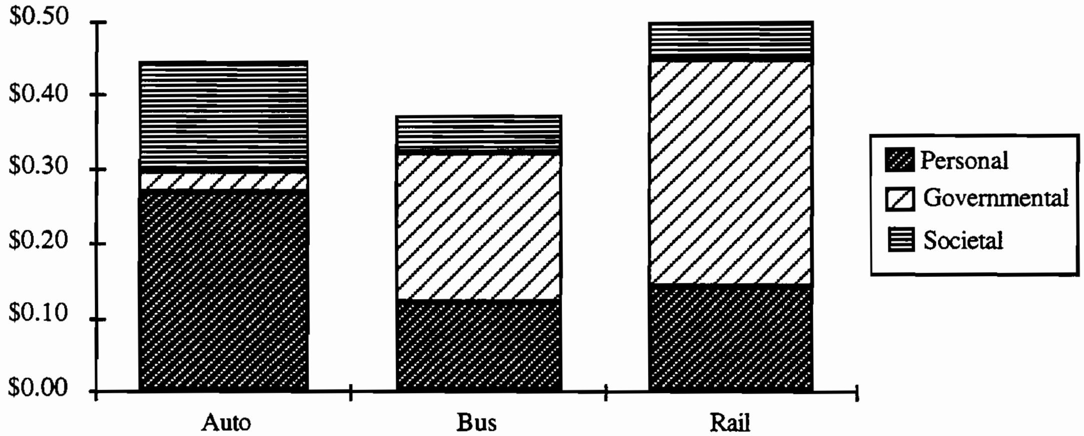

Figure 5.1 Average Transportation Costs by Modes

The external costs addressed in this review have been shown to be significant contributors to the total system costs of transportation. Implementing a system of charging those responsible for producing the externalities could result in a more efficient transportation system. If charged directly for the costs of externalities, a traveler would be forced to recognize the effects of the trip on society and on the surrounding environment. Society would benefit by implementing the full-cost analysis approach in that motorists would better understand the impact of their actions and would be better equipped to make informed transportation choices.

The major problem associated with the implementation of full-cost analysis is the lack of a method to compare transportation modes in a multimodal framework. Because transportation costs vary widely depending on location, time of day, fuel price, weather conditions, and other factors, the national averages presented in this report are not likely to be representative of any particular situation. It is obvious that the cost of driving in downtown Houston or Dallas differs substantially from the cost of driving in a small town in West Texas. In general, policy decisions regarding specific transportation facilities should be based on a careful evaluation of both the actual costs and benefits in each particular situation. The national estimates may not be the best method for determining the total cost of transportation for a particular site.

Accordingly, the research team has developed MODECOST — a full-cost transportation model. MODECOST is a tool that allows for the inclusion of cost components relevant to a transportation investment decision. The MODECOST model (see Report 1356-2) has been demonstrated in case studies undertaken in Houston (Reports 1356-3 and 1356-5), San Angelo (Report 1356-4), Dallas (Report 1356-6), El Paso (Report 1356-7), and San Antonio (Report 1356-8).

Table 5.1 The Full Cost of Transportation

		Cost ($ per PMT)			
Cost Category	Study	Study Area	Car	Bus	Rail
Capital & Local Government	P. Miller and J. Moffet (1993)	U.S.	0.025 - 0.030	0.201	0.311
Personal	P. Miller and J. Moffet (1993)	U.S.	0.250 - 0.300	0.120	0.140
	FHWA (1992)	U.S.	0.287 - 0.446	-	-
Indirect Parking	P. Miller and J. Moffet (1993)	U.S.	0.008 - 0.032	-	-
	Apogee Inc. (1994)	Boston	0.102 - 0.265	-	-
	Apogee Inc. (1994)	Portland	0.039 - 0.158	-	-
	KPMG (1993)	Vancouver	0.994	-	-
Congestion	P. Miller and J. Moffet (1993)	U.S.	0.0035	-	-
	GAO (1989)	U.S.	0.062 - 0.073	-	-
Accident (not from Users)	P. Miller and J. Moffet (1993)	U.S.	0.033	0.007	0.006
	Urban Institute (1991)	U.S.	0.019	-	-
	Apogee Inc. (1994)	Boston	0.010 - 0.057	0.019	0.016
	Apogee Inc. (1994)	Portland	0.013 - 0.064	0.079 - 0.091	-
Air Pollution	P. Miller and J. Moffet (1993)	U.S.	0.040 - 0.070	0.016 - 0.045	0.015 - 0.050
	FHWA (1982)	U.S.	0.024	-	-
	Litman (1992)	U.S.	0.016 - 0.115	-	-
	DeLuchi (1987)	U.S.	0.009 - 0.073	-	-
	MacKenzie (1992)*	U.S.	0.012	-	-
Energy	P. Miller and J. Moffet (1993)	U.S.	0.015 - 0.050	0.0085 - 0.028	0.0039 - 0.013
Noise	P. Miller and J. Moffet (1993)	U.S.	0.0014 - 0.0023	0.0005 - 0.0010	0.0016
	FHWA (1982)	U.S.	0.0016	-	-
	MacKenzie (1992)	U.S.	0.0047	-	-
	KPMG (1993)	Vancouver	0.0128	-	-
	Apogee Inc. (1994)	Boston	0.001 - 0.002	0.002 - 0.005	0.001 - 0.004
	Apogee Inc. (1994).	Boston	0.001	0.002	-
Building Damage	P. Miller and J. Moffet (1993)	U.S.	0.001	-	-
Water Pollution	P. Miller and J. Moffet (1993)	U.S.	0.0013	-	-
	KPMG (1993)	Vancouver	0.0016	-	-
Wetlands	N/A	-	-	-	-
Land Loss	Apogee Inc. (1994)	U.S.	0.020	-	-
	KPMG (1993)	Vancouver	0.014	-	-
Loss of Aesthetics	N/A	-	-	-	-
Loss of Property Value	N/A	-	-	-	-
Transportation Equity	N/A	-	-	-	-

*MacKenzie's 1992 study did not include the costs of acid rain, chronic health problems, carbon monoxide health impacts, or forest damages from low-altitude ozone.

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