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Review of Some of the Literature on the Social Cost of Motor-Vehicle Use

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REVIEW OF SOME OF THE LITERATURE ON THE SOCIAL COST OF MOTOR-VEHICLE USE

Report #3 in the series: *The Annualized Social Cost of Motor-Vehicle Use in the United States, based on 1990-1991 Data*

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REPORTS IN THE SOCIAL-COST SERIES

There are 20 reports in this series. Each report has the publication number UCD-ITS-RR-96-3 (#), where the # in parentheses is the report number:

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Report 2: Some Conceptual and Methodological Issues in the Analysis of the Social Cost of Motor-Vehicle Use (M. Delucchi)
Report 3: Review of Some of the Literature on the Social Cost of Motor-Vehicle Use (J. Murphy and M. Delucchi)
Report 4: Personal Nonmonetary Costs of Motor-Vehicle Use (M. Delucchi)
Report 5: Motor-Vehicle Goods and Services Priced in the Private Sector (M. Delucchi)
Report 6: Motor-Vehicle Goods and Services Bundled in the Private Sector (M. Delucchi, with J. Murphy)
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Report 8: Monetary Externalities of Motor-Vehicle Use (M. Delucchi)
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Report 15: U.S. Military Expenditures to Protect the Use of Persian-Gulf Oil for Motor Vehicles (M. Delucchi and J. Murphy)
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LIST OF ACRONYMS AND ABBREVIATIONS AND OTHER NAMES

The following are used throughout all 20 reports of the series, although not necessarily in this particular report

AER = *Annual Energy Review* (Energy Information Administration)
AHS = *American Housing Survey* (Bureau of the Census and others)
ARB = Air Resources Board
BLS = Bureau of Labor Statistics (U. S. Department of Labor)
BEA = Bureau of Economic Analysis (U. S. Department of Commerce)
BTS = Bureau of Transportation Statistics (U. S. Department of Transportation)
CARB = California Air Resources Board
CMB = chemical mass-balance [model]
CO = carbon monoxide
dB = decibel
DOE = Department of Energy
DOT = Department of Transportation
EIA = Energy Information Administration (U. S. Department of Energy)
EPA = United States Environmental Protection Agency
EMFAC = California's emission-factor model
FHWA = Federal Highway Administration (U. S. Department of Transportation)
FTA = Federal Transit Administration (U. S. Department of Transportation)
GNP = Gross National Product
GSA = General Services Administration
HC = hydrocarbon
HDDT = heavy-duty diesel truck
HDDV = heavy-duty diesel vehicle
HDGT = heavy-duty gasoline truck
HDGV = heavy-duty gasoline vehicle
HDT = heavy-duty truck
HDV = heavy-duty vehicle
HU = housing unit
IEA = International Energy Agency
IMPC = Institutional and Municipal Parking Congress
LDDT = light-duty diesel truck
LDDV = light-duty diesel vehicle
LDGT = light-duty gasoline truck
LDGV = light-duty gasoline vehicle
LDT = light-duty truck
LDV = light-duty vehicle
MC = marginal cost
MOBILE5 = EPA's mobile-source emission-factor model.
MSC = marginal social cost

MV = motor vehicle
NIPA = National Income Product Accounts
NO_x = nitrogen oxides
NPTS = Nationwide Personal Transportation Survey
OECD = Organization for Economic Cooperation and Development
O_3 = ozone
OTA = Office of Technology Assessment (U. S. Congress; now defunct)
PART5 = EPA's mobile-source particulate emission-factor model
PCE = Personal Consumption Expenditures (in the National Income Product Accounts)
PM = particulate matter
PM_{10} = particulate matter of 10 micrometers or less aerodynamic diameter
$PM_{2.5}$ = particulate matter of 2.5 micrometers or less aerodynamic diameter
PMT = person-miles of travel
RECS = Residential Energy Consumption Survey
SIC = standard industrial classification
SO_x = sulfur oxides
TIA = *Transportation in America*
TSP = total suspended particulate matter
TIUS = *Truck Inventory and Use Survey* (U. S. Bureau of the Census)
USDOE = U. S. Department of Energy
USDOL = U. S. Department of Labor
USDOT = U. S. Department of Transportation
VMT = vehicle-miles of travel
VOC = volatile organic compound
WTP = willingness-to-pay

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3. REVIEW OF SOME OF THE LITERATURE ON THE SOCIAL COST OF MOTOR-VEHICLE USE

3.1 INTRODUCTION

3.1.1 The context

Over the past five years, analysts and policy makers have become increasingly interested in the full social cost of motor-vehicle use. Researchers have performed social-cost analyses for a variety reasons, and have used them in a variety of ways, to support a wide range of policy positions. Some researchers have used social-cost analyses to argue that motor vehicles and gasoline are terrifically underpriced, while others have used them to downplay the need for drastic policy intervention in the transportation sector. In any case, social-cost analyses excite considerable interest, if only because nearly all of us use motor vehicles.

Interest in full social-cost accounting and socially efficient pricing has developed relatively recently. From the 1920s to the 1960s, major decisions about building and financing highways were left to "technical experts," chiefly engineers, who rarely if ever performed social cost-benefit analyses. Starting in the late 1960s, however, "a growing awareness of the human and environmental costs of roads, dams, and other infrastructure projects brought the public's faith in experts to an end" (Gifford, 1993, p. 41). It was a short step from awareness to quantification of the costs not normally included in the narrow financial calculations of the technical experts of the past.

Today, discussions of the social costs of transportation are routine. In most accounts, the "social" cost of transportation includes external, nonmarket, or unpriced costs, such as air pollution costs, as well as private or market costs, such as the cost of vehicles themselves. Government expenditures on motor-vehicle infrastructure and services usually are included as well.

Not surprisingly, however, there is little agreement about precisely which costs should be counted, which costs are the largest, how much the social cost exceeds the market or private cost, or to what extent, if any, motor-vehicle use is "underpriced." On the one hand, many recent analyses argue that the "unpaid" or external costs of motor-vehicle use are quite large — perhaps hundreds of billions of dollars per year — and hence that automobile use is heavily "subsidized" and underpriced (e.g., MacKenzie et al., 1992; Miller and Moffet, 1993; Behrens et al., 1992; California Energy Commission, 1994; Apogee Research, 1993; COWIconsult, 1991; KPMG, 1993; Ketcham and Komanoff , 1992; Litman, 1996). But others have argued that this is not true. For example, the National Research Council (NRC), in its review and analysis of automotive fuel economy, claims that "some economists argue that the societal costs of the 'externalities' associated with the use of gasoline (e.g., national security and environmental impacts) are reflected in the price and that no additional efforts to reduce automotive fuel consumption are warranted" (NRC, 1992, p. 25). Green (1995) makes essentially the same argument. Beshers (1994) and Lockyer and Hill (1992) make the narrower claim that road-user tax and fee payments at least equal government expenditures related to motor-vehicle use, and Dougher (1995) actually argues that road-user payments exceed related government outlays by a comfortable margin.

We could cite other examples. This extraordinary disagreement exists because of differing accounting systems, analytical methods, assumptions, and data sources. The root of the problem is that there are few detailed, up-to-date, conceptually sound analyses. With few exceptions, the recent estimates in the literature are based on reviews of old and often superficial cost studies. Moreover, some of the current work is confused about the meaning of "externality," "opportunity cost," and other economic concepts.

In this situation, policy makers and others who wish to apply estimates of the social cost of motor-vehicle use might find it useful to have most of the major estimates summarized and evaluated in one place. This then is the purpose of our paper: to review and evaluate much of the present literature on the social-cost of motor-vehicle use, which can serve as an aid to those who wish to use the estimates.

3.1.2 Our review

In this paper, we review much of the existing literature on the social cost of motor-vehicle use. The studies reviewed are presented in chronological order. Generally, we review the purpose, scope, and conclusions, and summarize the cost estimates by individual cost category. We also assess the degree of originality and detail of each major cost estimate in each of the studies.

In each review, the definitions and terms are those of the original study. For example, we report as an "external cost" what each study calls an external cost; we do not define external cost ourselves and then categorize estimates of each study with respect to this definition. This of course means that what may appear in different studies to be estimates of the same cost — the "external cost" of accidents, for example — might actually be estimates of different costs. Because of this, and because of differences in scope, time frame, and so on, one must be careful when comparing estimates.

Our review consists of a set of relatively detailed reviews, with tabulations of the estimates and the degree of originality and detail by cost item, and a set of brief, untabulated reviews. In the main set of detailed reviews, we include only studies whose primary purpose is to estimate some significant part of the social-cost of motor-vehicle use. We do not include studies where the use, review, or development of estimates is secondary to application or theoretical discussion. Also, we do not include estimates of a single cost item, such as air pollution. However, such studies are reviewed in the appropriate report in our Social Cost series (see page ii for a listing of the reports in this series).

3.2 KEELER AND SMALL (1975)

3.2.1 Introduction

Keeler and Small (1975) is one of the most influential and widely cited studies of the costs associated with automobile use. It was one of the first attempts to quantify the non-market costs of automobile use, such as time and pollution, as well as the direct costs, such as operation and maintenance. Although most of the costs in this report are now outdated, and many of the methods have been improved, we summarize Keeler and Small (1975) because of its influence on subsequent research.

3.2.2. Goals and Methodology

This report develops estimates of the costs of peak-hour automobile transportation in the San Francisco Bay Area. To facilitate intermodal comparisons, the authors also develop similar cost estimates for bus and rail work trips. They divide automobile trips into three main components, and estimate costs associated with each: (1) residential collection (i.e. going from a residence to the freeway interchange), (2) line-haul trip (i.e. travel by freeway to edge of central business district), (3) downtown distribution. They evaluate two alternative trip lengths: (1) a six-mile line-haul trip with an average feeder distance of one mile, and (2) a 12-mile trip with an average feeder distance of 2 miles. For both trips, the downtown distribution is assumed to be about 0.75 miles in length.

3.2.3 Capital and Maintenance Costs

To estimate highway capacity costs, Keeler and Small (1975) develop statistical cost models for construction, land acquisition, and maintenance. The data used in the three models covers all state-maintained roads in the Bay Area, including expressways, arterials and rural roads. The construction-cost model, which accounts statistically for the effects of urbanization and economics of scale on expressway construction costs, allows them to estimate the cost of a lane-mile of freeway under different degrees of urbanization and road widths. The general specification for the models is:

Construction Costs: $KLM = f(CRS, CUC, FR, FSU, FC, W)$

Land Acquisition Costs: $ROW/K = g(CRS, CUC, FR, FSU, FC)$

Maintenance Costs: $MC/LM = h(V/L)$

where KLM is 1972 construction cost per lane-mile, CRS is the fraction of road length in the sample accounted for by rural roads, CUC is the fraction of arterial streets, FR is fraction of rural freeways, FSU is fraction of urban or suburban freeways, FC is fraction of freeways within city limits, V is average number of lanes in the observed stretch of road, ROW/K is right-of way costs as a fraction of construction costs, MC/LM is maintenance costs per lane-mile, and V/L is average annual vehicles per lane on the relevant stretch of road.

3.2.4 User Benefits and Costs of Speed

Keeler and Small (1975) recognize that there is a trade-off between highway traffic speed and capacity utilization: faster speeds save travel time, but result in lower capacity utilization and increased fuel consumption[1]. (This tradeoff is represented by speed-flow curves). They develop a model which calculates optimal tolls and volume-capacity ratios for each period as a function of time values and lane capacity costs. To develop the model, the authors adjusted the results of a study by the Institute of Transportation and Traffic Engineering that estimated speed-flow curves for the Bay Area. On the basis of a literature review, they that assume the value of time in the vehicle is three dollars per hour per person. Finally, they use data on hourly vehicle flows to determine the peaking characteristics of traffic.

3.2.5 Public Costs

For Keeler and Small (1975), public costs include environmental costs, the costs of police and supporting social services (e.g. city planning, fire department, courts, etc.), and any maintenance costs that are related to the numbers of vehicles that use the road (as opposed to those costs which are related to the capacity of the road). To estimate police and social service costs, the authors cite an earlier unpublished paper (Keeler, et al., 1974), in which they estimate the average costs of police and supporting social services was about 4.5 mills per vehicle-mile in the Bay Area. They assume that the marginal and average costs are about the same.

Their estimate of the environmental costs (i.e. noise and pollution) are drawn from a previous paper (Keeler and Small, 1974). They argue that marginal noise costs are likely to be low, no more than one or two mills per vehicle mile, because costs are high only on quiet residential streets where an extra vehicle is likely to be noticed. They estimate that 1973 composite pollution (the average from all vehicle types) costs about 0.92 cents per vehicle-mile. They note that this is a conservative figure because it assumes that the cost of human illness and death is only equal to hospital bills and foregone wages. On the other hand, they expect that this cost will decline as more rigorous standards come into effect.

3.2.6 Accidents and Parking Costs

To estimate accident costs, Keeler and Small (1975) first compute a national average accident cost figure, and then use the results of two earlier studies (May, 1955; Kihlberg and Tharp, 1968) to allocate highway costs among the different highway types and locations. Parking costs were derived by combining the results of two engineering cost studies (Meyer, et al., 1965; Wilbur Smith and Associates, 1965). From this, they derived estimates of the annual cost per parking space for five types of facilities (lot on CBD fringe, lot in low land value CBD, garage in low-, medium-, and high-value CBD). They did an informal comparison of the results of these studies with actual rates at privately-owned parking facilities in San Francisco and found that they were consistent.

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[1]However, fuel consumption is not by any means a simple linear function of speed, and in some cases a increase in the overall average speed reduces fuel consumption.

Table 3.1 provides a sample of Keeler and Small's results.

3.2.7 Related work

The work of Keeler and Small (1975) spawned additional work on air pollution costs, by Small (1977). Small's (1977) objective was "to provide some rough and aggregate measures of the economic costs imposed on society by air pollution from various transport modes in urban areas." Small used the work of Rice (1966), Lave and Seskin (1970), and the Midwest Research Institute (1970) to estimate the total health and materials costs of air pollution. He then disaggregated the total pollution cost by specific pollutant and geography. Finally, he estimated the motor-vehicle contribution to each pollutant and hence to air pollutant damages. The result was an estimate of $1.64 billion in air-pollution damages by automobiles, and $0.55 billion by trucks, in 1974.

3.3 FEDERAL HIGHWAY ADMINISTRATION (1982)

3.3.1 Goals and Methodology

In the introduction, the authors state:

> This report...responds to the [Congressional] request for: (1) an allocation of Federal highway program costs among the various classes of highway vehicles occasioning such costs; (2) an assessment of the current Federal user charges and recommendations on any more equitable alternatives; and (3) an evaluation of the need for long-term monitoring of roadway deterioration due to traffic and other factors (page I-1).

Although the primary focus of the report is the allocation of Federal highway expenditures, Appendix E of the report contains a discussion of some of the social costs and provides estimates of efficient highway user charges for some of these costs in 1981.[2] Table 3.2 lists all of the variable costs identified in the report.[3] Of the 11 cost items mentioned, the authors attempt to estimate costs, on a vehicle mile traveled (VMT) basis, for six (pavement repairs, vibration damages to vehicles, administration, congestion, air pollution and noise). Costs associated with the first two of these items are significant for trucks, but negligible for automobiles on a VMT basis. The authors note that of the five costs not estimated in cents per VMT, "accidents looks to be the only category that might lead to a substantial increase in user charges if more were known about causal relationships. Other marginal costs may be large in the aggregate

[2] "Efficient highway user charges are those which will lead to the greatest surplus of benefits over costs, for a given stock of capital facilities" (page E-17).

[3] The authors focus solely on variable costs. They do not consider costs, such as the environmental or neighborhood impacts resulting from highway constructionthey exclude impacts, that are not changed by the amount of usage (i.e., that occur whether or not the highway has any traffic) .

but small in relation to VMT" (page E-52). In their conclusion, they estimate that "efficient user charges could raise almost $80 billion annually (ignoring collection costs and assuming revenues from different types of charges are additive), in contrast to the $40 billion currently spent on highways by all levels of government or the $22 billion now raised by user fees" (page E-7).

In addition, Appendix E also contains a fairly detailed discussion of the standard economic theory upon which their social-cost analysis is based.

3.3.2 Pavement Wear

According to the FHWA, "damage to the surface of the pavement is caused by the passage of a vehicle and depends upon the axle loads imposed by the vehicle and the strength of the pavement. The direct costs of this wear are represented by either the costs of restoring the pavement to its original condition or the loss of user benefits from not restoring the pavements. Indirect costs occur to users due to delay, vehicle wear, fuel consumption, accidents, and discomfort from operating on rough pavement" (page E-16).

The FHWA (1982) estimates two cost components to pavement wear: the cost of repairing the pavement damage, and the additional cost to users which result from traveling on damaged roadways. They use FHWA data on average gross weight and VMT for each vehicle class to estimate pavement wear costs. Additional user costs include increased vehicle wear, fuel consumption and other operating costs, travel time, accidents and discomfort.

3.3.3 Administration and Services

"Several costs associated with administration of the highway system and providing services to highway users can be regarded as variable costs. Requirements for traffic police and vehicle code enforcement tend to go up with vehicle volumes. Some accident costs, such as police response, emergency public medical treatment, can court expenses for liability litigation are not included in private insurance premiums" (page E-16). On the basis of a review of the literature, FHWA (1982) estimates that administration costs are about $0.004 per vehicle mile in urban areas.

3.3.4 Vehicle Interference

"Congestion is the result of interaction between the limited vehicle capacity of a given facility and the demands for space by individual users. The costs of congestion occur in the form of excess travel time, increased expected damage and injury from accidents among vehicles, and additional vehicle operating costs for wear and fuel. All are measured relative to what the costs would be under uncongested or free flow conditions" (page E-16).

Their estimate of congestion costs is relatively straightforward. It is based primarily upon traffic volumes, volume-to-capacity ratios, and the changes in travel time the result from increased traffic.

However, their estimate of accident costs rests on the perhaps misleading assumption that "liability for the accident is immaterial; if the driver who is 'not at fault' had stayed home and thereby avoided the accident, then the costs of the accident are just as much a consequence of his or her decision to make the trip as they are a consequence of the driver supposedly at fault" (page E-36). Although it is true that had the "blameless" driver stayed at home, the accident might have been avoided, it does not follow from this that blameless driver as well as the driver at fault both should be assigned the full cost of the accident as an externality. Rather, each driver should be charged for the external cost imposed upon the other, and left to bear without compensation the entire cost to himself. Thus, the correct total externality charge does not exceed the total cost of the accident.

3.3.5 Negative Externalities

"Air pollution and noise are real costs to members of society even though dollar amounts do not appear in public budgets... The higher the rate of emissions from a vehicle and the more sensitive and more numerous the persons impacted, the higher is the marginal cost of a vehicle trip. The essential characteristic of an externality is that it escapes normal market transactions, so that the valuation of negative external effects must be accomplished by political or other surrogate means" (page E-16). The authors acknowledge that water pollution from motor vehicle use probably generates a significant cost, but claim that "insufficient evidence currently exists to attempt to estimate efficient prices" (page E-46).

The FHWA's estimates of the cost of air pollution and noise (Table 3.2) are based primarily on literature reviews, but are supplemented with original analysis. The estimate of noise costs is based on the work of Fuller, et al. (1983).

3.4 KANAFANI (1983)

3.4.1 Summary

"The purpose of this report is to review and assess recent attempts at the evaluation of the social costs of road transport. It is intended to provide a comparative evaluation of the economic magnitude of the social costs of road transport in selected countries, particularly as occasioned by the environmental and safety impacts of motor transport" (page 3).

Kanafani's (1983) report is a review of published estimates of the social costs of motor-vehicle noise, air pollution and accidents. He defines social costs as "those costs that are incurred by society as a whole, not solely by the users as direct costs, nor those that are incurred solely by the nonusers" (pages 2-3). He discusses the key cost components for each of these categories, and summarizes the results from other studies.

Kanafani reviews studies from several different countries, including the United States, France and West Germany. Table 3.3 shows the results of his review of studies of the social cost of motor-vehicle use in the United States.

3.5 FULLER ET AL. (1983)

3.5.1 Background and scope

This report was prepared in conjunction with the FHWA Cost Allocation Study (FHWA, 1982). Although the FHWA report does discuss external costs (see Section 3.3 of this paper), its primary focus is on allocating government outlays. Fuller, et al. (1983) on the other hand, focus exclusively on external costs. The costs identified in this report are: congestion or interference (which includes accidents), air pollution, and noise damages. The analysis was performed using data for 1976 to 1979, with forecasts for 1985.

Although the report "does not undertake to develop new techniques for the measurement of damages," and instead performs "a comprehensive review of the literature and data available for each type of damage" (page 4), it does in fact use detailed models to estimate marginal and total costs, particularly noise costs.

3.5.2 Congestion and accident costs

Fuller et al. (1983) model traffic interference (time / VMT) and marginal accident rates (rate / 10^8 VMT) as a function of the volume / capacity ratio on several different functional classes of roads (interstates, arterials, collectors, and local roads in rural and urban areas). They combine these functions with estimates of the value of time by functional road class, and the injury, fatality, and property-damage costs of accidents, to produce marginal-cost curves ($ / passenger-car-equivalent VMT) for the different functional classes of roads.

3.5.3 Air pollution costs

Fuller et al. (1983) estimate air-pollution costs in three steps. First, they review and analyze the literature on the health, vegetation, and materials damages of air pollution (e.g., Small [1977]; Lave and Seskin [1970]) in order to estimate dollar damages per ton of each pollutant. Second, they multiply the $ / ton estimates by the EPA's estimates of g / mi emissions, for each pollutant, and sum across all of the pollutants, to obtain $ / VMT. Finally, they "correct" the $ / VMT estimates for "microscale" differences in exposure, meteorology, and other factors.

3.5.4 Noise costs

Fuller et al. (1983) calculate the dollar cost of motor-vehicle noise in residential areas as the product of three factors:

(1) the number of housing units in each of up to three distance / noise bands along roads: the band of "moderate" exposure (55 to 65 dBA), the band of "significant" exposure (65 to 75 dBA), and the band of "severe" exposure (more than 75 dBA);

(2) "excess" dBA of noise, equal to the noise level at the midpoint of each distance / noise band minus the threshold noise level (assumed to be 55 dBA);

(3) the dollar reduction in property value per excess dBA (estimated to be $152 / excess-dBA [1977$]).

They use a 1970s-vintage noise-generation equation to delineate the distance / noise bands, and national-average data on housing density, housing value, and traffic volume. They do not consider noise costs outside of the home.

The work of Fuller, et al. (1983) were incorporated into the FHWA (1982) study, summarized in Table 3.2. Their results have been cited in a number of studies.

3.6 MACKENZIE ET AL. (1992)

Because this is one of the most widely cited studies on the social cost of motor vehicle use in the United States, we review it in detail.

3.6.1 Goals and Methodology

The goal of this paper is to quantify in the U.S. the costs of motor vehicle use that are not borne by drivers.

There are two types of costs identified in this study: markets costs, and external costs. "Market costs are those that are actually reflected in economic transactions...(They) represent the direct, ordinary, expected costs of owning and operating a motor vehicle" (page 7). Examples of this include vehicle purchase, fuel and maintenance costs, and road construction and repair. External costs, or externalities, are those costs, such as global warming and illnesses resulting from pollution, that are not incorporated into market transactions. Social costs are the sum of market and external costs. All cost estimates in MacKenzie et al. (1992) are for fiscal year 1989, and are in 1989 dollars.

Most of the cost estimates provided by MacKenzie, et al. (1992) are derived from previous studies. In most cases their estimate either is direct citation from another work, or else a simple extrapolation from someone else's analysis. They find that the annual market cost not borne by drivers in 1989 was about $174.2 billion, and the annual external cost not borne by drivers in 1989 totaled $126.3 billion. These two figures combined result in an estimate of the total annual social costs of roughly $300 billion in the United States in 1989.

The results of this study are summarized in Table 3.4, and reviewed in more detail in the following sections.

3.6.2 Highway Construction, Repair and Maintenance

Their estimates of the cost of highway construction, improvement and repair ($33.3 billion); highway maintenance ($19.7 billion); and other highway-related disbursements ($18.2 billion) are taken directly from the Federal Highway Administration's report on highway finances (FHWA, 1990). The FHWA (1990) also estimates that gasoline taxes and other user fees contributed approximately $20 billion toward roadway construction and repair, and $12 billion toward routine roadway maintenance. The remaining expenditures were financed by taxpayers in general, not necessarily by motorists.

3.6.3 Highway Services

MacKenzie et al.'s (1992) estimate of the cost of highway services is from Hart's (1986) summary of his own earlier, more detailed analysis (Hart, 1985). See the review of Hart (1985, 1986) in section 3.19 for a more detailed explanation of Hart's estimates.

In this category, MacKenzie et al. (1992) mean to include police motorcycle patrols and details for auto theft, parking enforcement, accident aid, fighting garage fires, and various public works expenses, such as traffic and road engineering.

As discussed below, Hart's (1986) estimate of the national cost of highway services is an extrapolation of his detailed estimate for the city of Pasadena. This extrapolation is questionable. Moreover, it appears that some of the costs that Hart and hence MacKenzie et al. (who use Hart's work) count as highway-service costs actually are highway capital and operating costs in the FHWA's (1990) report. Thus, some of the highway service costs (some of what Hart classifies as "public works" and "capital improvements") estimated here are double counted with highway capital and operating costs.

3.6.4 Employer Paid Parking

MacKenzie, et al. (1992) assume that 86% of the workforce commutes by car, and that 90% receives free parking, and then calculate that 85 million Americans receive free parking at work. Assuming that the average national value of a parking space was $1000 (Association for Commuter Transportation, 1990), MacKenzie, et al. (1992) estimate that the annual parking subsidy for workers is about $85 billion.

MacKenzie et al.'s (1992) estimate depends on several assumptions that could be improved upon somewhat. First, they assume that every car has only one person during the commute to work. This is a bit low: according to the 1990 Nationwide Personal Transportation Study (Hu and Young, 1992), the vehicle occupancy rate for the journey to work was 1.1 persons per vehicle. Second, it appears that MacKenzie et al. assume that there are 109.8 million workers. However, according to the U.S. Department of Labor, the total number of workers in April 1992 was 119.2 million. Third, they cite a 1987 study by Pisarski that estimates that 86% of the workers used private transportation in 1980. However, the preliminary report of the Nationwide Personal Transportation Study (NPTS) for 1990 estimates that this has increased to around 91% (Hu and Young, 1992). Fourth, and most seriously, they assume that the national average price of a parking space is $1,000 per year. We believe that this is too high, perhaps by several hundred dollars.

MacKenzie et al. note that theirs is an estimate of the cost of free parking for work trips, and therefore it does not include the cost of free parking for other kinds of trips. Because commuting to work constitutes only 26% of all vehicle trips, the cost of free parking for the non-work trips obviously will not be trivial. According to the 1990 NPTS, the remaining 74% of trips were distributed as follows: shopping, school, church, medical, 27%; other personal business, 24%; social and recreational, 20%; and other, 3% (Hu and Young, 1992).

3.6.5 Air Pollution

Based on a literature review, MacKenzie, et al. (1992) make a “conservative” estimate that motor-vehicle air pollution causes $10 billion in damages annually. No details are provided on the derivation, beyond citing estimates from other studies. Presumably, this estimate includes health costs, lost agricultural productivity, reduced visibility, etc. They note that there are a number of uncertainties which can significantly effect this estimate.

3.6.6 Climate Change

Because there is so much uncertainty about the magnitude, effects, and costs of climate change, MacKenzie, et al. (1992) assume that “it is not possible to accurately estimate the actual costs of the current buildup of greenhouse gases” (page 14). In order to develop an “imperfect” estimate, they use Jorgenson and Wilcoxen’s (1991) results. Jorgenson and Wilcoxen (1991) estimate that a phased-in carbon tax that reached $60 per ton of carbon emissions (which translates to about 20 cents per gallon of gasoline) in the year 2020 would reduce emissions to 80% of the 1990 level by 2005. By assuming that motor-vehicle fuel consumption would continue at roughly 1990 levels, MacKenzie, et al. (1992) estimate that a phased-in tax of 20 cents per gallon would eventually cost motorists about $27 billion per year. They use the $27 billion figure as an estimate of the cost of climate change.

We emphasize that this is not an estimate of the damage cost of global warming at all, but rather an estimate of the aggregate revenue from a somewhat arbitrarily assumed carbon tax on gasoline.

3.6.7 Security Costs Of Imported Oil

Ravenal (1991) estimates that the United States spends about $50 billion to maintain a military presence in the Middle East. MacKenzie, et al. (1992) allocate half of this to motor vehicles on the grounds that motor vehicles consume half of the total petroleum supply in the United States. For the same reason, MacKenzie et al. also allocate to motor vehicles half of the $500 million per year cost of maintenance and oil acquisition for the Strategic Petroleum Reserve. They conclude their discussion of security costs by noting that this estimate ($25.3 billion) may be high and warrants further analysis.

3.6.8 Congestion

On the basis of a review of three studies (Texas Transportation Institute, 1987; U.S. General Accounting Office, 1990; U.S. General Accounting Office, 1991a), MacKenzie, et al. (1992) estimate that the cost of congestion — productivity losses, excess fuel use and higher insurance premiums — is at least $100 billion per year, all of which is borne by drivers.

3.6.9 Accidents

MacKenzie, et al.’s (1992) estimate of the cost of accidents is taken directly from the Urban Institute (1991). The Urban Institute study accounts for the cost of lost wages and lost household productivity, property damage, medical, legal, administrative, and workplace costs, travel delay, emergency services, pain, suffering, and lost quality of life. Costs for these categories total $358.5 billion, of which $55.2 billion , according to MacKenzie et al. (1992), is not borne by drivers.

3.6.10 Noise

Hokanson et al. (1981) develop noise cost factors for cars and trucks on urban highways. MacKenzie, et al. (1992) update the analysis of Hokanson et al. (1981) with 1989 data, and estimate that the total noise damage from cars and trucks in 1989 was about $9 billion. Eighty-five percent of this was due to trucks.

3.7 KETCHAM AND KOMANOFF (1992)

3.7.1 Goals and Methodology

Ketcham and Komanoff (1992) are concerned about the inefficient use of New York City's transportation infrastructure. They feel that the compactness of New York City creates an opportunity to provide people with a greater variety of transportation alternatives, but that public policies are skewed towards motor-vehicle use and prevent these opportunities from materializing. They believe that New York City's "transportation and air pollution problems are solvable, through an approach that systematically charges motorists for a fair share of the fiscal and social costs of driving and invests much of the revenues in transit and other non-motorized modes" (page 3). Their paper explains this approach, and how it can "benefit the vast majority of residents in the region" (page 3).

In their report, costs are divided into four categories: i) The costs that motorists themselves pay in order to drive are called "the direct costs of roadway transportation borne by users." Examples of these direct costs include vehicle purchase, fuel, insurance, and maintenance and repair. ii) The costs of building and maintaining roads in excess of user fees such as tolls and taxes are called "the direct costs of roadway transportation borne by non-users." iii) The portion of motor-vehicle externalities, such as congestion, noise and accidents, that is borne by motorists in the act of driving is called "the externality costs borne by users." iv) Finally, environmental damages and other external costs that are borne by society as a whole are called "externalities borne by non-users."

Much of the paper is devoted to public policy issues that focus primarily on New York City. However, a portion of the paper provides an analysis of the social costs of motor vehicle use for the whole United States. Our review focuses on Ketcham and Komanoff's (1992) national estimates, most of which they derived from their review of other published studies, particularly the FHWA (1982), Eno Foundation (1991), and MacKenzie, et al. (1992). The results of their study are shown in Table 3.5, and discussed in more detail in the following.

3.7.2 Direct Costs of Roadway Transportation

Ketcham and Komanoff's (1992) estimates of the direct costs borne by drivers — vehicle ownership, taxi services, school bus transport, and freight movement by truck — are from the Eno Foundation (1991). They do not estimate the national costs associated with off-street parking. Their estimates of the direct costs not born by drivers — costs associated with roadway construction, maintenance, administration and services — are calculated from Federal Highway Administration data on highway finances (FHWA, 1990).

3.7.3 Externalities of Roadway Transportation

Accidents and congestion. In Ketcham and Komanoff, the two largest external costs are congestion ($168 billion) and accidents ($363 billion), which combined represent almost 75% of their total estimated external costs of roadway transport. To estimate congestion costs they used the cost factors in the FHWA Cost Allocation Study (FHWA, 1982); they adjusted the factors to 1990 dollars, but not to 1990 congestion intensity levels. Their estimate of the national cost of motor-vehicle accidents is from the Urban Institute (1991). The bulk of these two external costs is borne by users.

Land costs. According to Ketcham and Komanoff (1992), the land cost of motor-vehicle use is one of the largest external costs borne by non-drivers. They estimate the land cost nationally by scaling the estimated cost in New York City. They estimate the cost in New York City on the basis of three assumptions: that street space is one-third of the city's land area; that half of the street space is needed for movement of public vehicles, bicycles and pedestrians (and therefore is not to be assigned to motor-vehicle use), and that the value of the land in New York City is 45% of the city's $26 billion budget derived from property taxes. They then estimate the national land cost by scaling up the cost in New York City on the basis of population and labor force.

One can question all three of the assumptions that Ketcham and Komanoff use to estimate the value of land devoted to motor-vehicle use in New York City. Certainly, one can question the basis for scaling the result from New York City to the entire country. Beyond that, however, it is not clear to us why they consider all of the estimated land value to be an external cost: the FHWA's estimates of the cost of road construction (FHWA, 1990), which Ketcham and Komanoff use in their national analysis, include the cost of acquiring right-of-way for roads. Hence, at least some of the cost of the land is counted as an infrastructure cost, and is partially recovered from users through user fees.

Air pollution. Ketcham and Komanoff derive their estimate of the cost of air pollution from the estimates in the FHWA Cost Allocation study (FHWA, 1982), which the authors say are consistent with the ranges published in other studies. Actually, on basis of these other studies, the authors feel that their estimate of $30 billion is conservative.

Noise. A 1981 study for the FHWA by the Institute of Urban and Regional Research at the University of Iowa (Hokanson et al., 1981) estimates the nationwide costs of noise in 1977. Ketcham and Komanoff (1992) make four adjustments to this estimate: they update to 1990 dollars, increase the estimate by 50% to capture commercial as well as residential impacts, increase the estimate by 93% to reflect the change in VMT from 1977 to 1990, but then reduce the estimate by 10% to reflect improvements in engine noise abatement.

Vibration damages. The authors found no published estimates of vibration damage to buildings and infrastructure. They guess that vibration damages might be 50% of the cost of pavement repair on urban streets. (They do acknowledge that this essentially a guess).

They estimate vehicle damages due to poor road conditions on the basis of data in the 1982 FHWA Cost Allocation study (FHWA, 1982). Ketcham and Komanoff (1992) apply only half of the cost factors from that study to ensure that only damages to vehicles were included.

3.8 HANSON (1992)

3.8.1 Goals and Methodology

Hanson (1992) believes that automobile subsidies have encouraged a pattern of urban and regional sprawl. His article "delineates the nature and magnitude of automobile subsidies in the United States and considers their significance for transportation and land use policy. The central argument...is that the U.S. transportation system, based on and designed largely for the automobile, has been systematically subsidized in a way that produces a more dispersed settlement pattern than would have otherwise evolved" (page 60).

Hanson (1992) uses data provided by the state of Wisconsin, supplemented with a review of existing studies, to estimate these subsidies.[4] The state of Wisconsin is used because it is near the national average for the percentage of state highway user revenues shared with local governments, and because Wisconsin is unique in its extensive reporting requirements.

The results of Hanson's (1992) analysis are shown in Table 3.6, and discussed more below.

[4] An automobile subsidy is defined as any direct cost in providing for and using the automobile system that is not paid for privately or through a transportation fee.

3.8.2 Direct Costs

Hanson (1992) divides direct costs into three major categories. "Highway Construction" includes right-of-way acquisition, engineering, signing, and construction costs for pavement, bridges, culverts, and storm sewers. "Highway Maintenance" includes maintenance of pavements, bridges, culverts, storm sewers, and traffic control devices, and snow plowing. "Highway Infrastructure, Other" includes machinery and vehicles, buildings, debt service payments, and street lighting. Hanson (1992) analyzes government data to make these estimates. After estimating the gross direct costs, Hanson (1992) nets out offsetting user revenues to calculate the subsidy to motor vehicle use.

3.8.3 Externalities and Other Indirect Subsidies

Hanson (1992) estimates the external costs of air pollution, water pollution resulting from road salt use, personal injury and lost earnings associated with accidents, land use opportunity costs for land removed from other sources, and petroleum subsidies. Hanson (1992) points out that there are a number of other external costs, such as noise and community disruption, that he has not attempted to quantify.

In order to estimate air pollution costs for Madison, Wisconsin, he notes that the midpoint estimate in the studies of national costs that he reviewed was $7 billion. To allocate a share of this to Madison, Wisconsin, he multiplied this midpoint figure by the ratio of the population of Madison to the population of the United States.

To estimate the personal injury costs associated with accidents, Hanson (1992) multiplies the number of accidents in 1982 (1,628 according to the Wisconsin Department of Transportation, WDOT) by the personal injury cost per accident ($7,700). He also uses a WDOT estimate of the cost of lost earnings, $1.6 million. Note that these estimates do not assign value for fatalities.

Hanson (1992) also uses WDOT data to generate an estimate of the value of property damages resulting from accidents . However, in quantifying the amount of this which should be considered a subsidy, he assumes that "because a substantial portion of property damage is insured by automobile users via separate insurance coverage, and to a lesser degree by direct payments, those costs are mostly internalized and, therefore, not included."

Hanson (1992) assumes that "a land opportunity cost occurs when land, used for roads, could have been used for some other purpose." A subsidy will result if more than the "optimal" amount of land is used for highways. To provide a rough estimate of this subsidy, Hanson (1992) assumes that one-third of the surface area of highways in Madison is unnecessary. This is based on two assumptions. First, according to Cervero (1989), local roads provide 80% of the lane miles, but only 15% of the vehicle miles. Second, he assumes that higher travel costs would reduce travel demand and alter land use in the long run. He uses forgone property tax revenues to estimate the cost of land, and calculates that, with the existing property tax rates, Madison would gain $1 million in revenues if the area of roadways was reduced by one-third.

Hanson (1992) notes that air emissions from motor vehicles contribute to water pollution and acid rain, but believes that there are few reliable published estimates of the damages. As a result, he focuses only on damages from road salt. He begins with the estimates provided by Murray and Ernst (1976), adjusts their figures to avoid double counting, converts their estimate to 1983 dollars, and finally allocates a portion of the cost to Madison on the basis of the population in the snowbelt "salt zone."

To estimate petroleum subsidies, Hanson (1992) uses Hines' (1988) estimates of the depletion allowances and other tax breaks received by the petroleum industry in 1984. This is allocated to Madison by combining gasoline consumption for personal travel in Madison with the subsidy level per British thermal unit (BTU).

3.9 BEHRENS ET AL. (1992)

3.9.1 Goals and Methodology

"CRS (Congressional Research Service) was assigned by the Congress to summarize for the U.S. Alternative Fuels Council what is known about monetary estimates of the side effects (external costs) stemming from oil used in highway transportation" (summary, page 1).

There are three major cost categories included in this study: economic costs stemming from the dependence on world oil markets, national defense costs, and health and environmental impacts. Estimates of the costs associated with each of these is based on a review of previously published studies. From these studies, the authors attempt to develop what they believe are reasonable low- to mid-range estimates of the monetary value of these external costs.

The results of this study are summarized in Table 3.7. Their results are difficult to interpret because they are the product of a review of various studies which analyze different years. Behrens, et al. (1992) make no attempt to adjust these costs into current dollars, so the year to which their estimates apply and the base year used for the dollar figures are uncertain.

3.9.2 Economic Costs of Oil Dependence: risk of supply disruption, monopsony effects

"An external cost to oil imports is posited because the impacts on the economy from potential supply disruptions and price spikes are borne by society as a whole, not only those who use imported oil" (page 19). Behrens et al. (1992) consider two effects on the economy due to this oil dependency: the risk of disruption, and the market power or monopsony effect. The former is the result of exposure to "possible market manipulation or disruption by exporting nations" (page 7). Because the United States is so heavily dependent on oil, this risk is high and the costs associated with it can be significant. Some of the potential adverse impacts include higher inflation and unemployment, as well as possible balance of payments and exchange rate effects. The range of estimates of the costs associated with this range from zero to $10 per barrel. The variation in the estimates depends upon the assumptions, methods and types of costs included. Multiplying the results of a mid-range estimate by U.S. oil imports for 1990, the authors estimate a $6-9 billion cost to the economy for exposure to disruption risk.

"The market power or monopsony component reflects the influence on the world price that a large importer such as the United States causes" (page 7). The economic cost of this results from the foregone wealth transfer to U.S. citizens that could result from reducing U.S. oil imports (which would result in lower world oil prices). Based on a literature review, the authors use a mid-range estimate of $21-24 billion for not exploiting this power.

3.9.3 National defense costs

"The focus is on military expenditures that could be avoided if we and other industrialized countries did not need to import oil from the Persian Gulf or some other insecure area" (page 23). However, attributing military expenditures to the defense of Persian Gulf oil interests is not straightforward. This section of their report contains a discussion of the problems associated with this, particularly with the uncertainties resulting from the end of the Cold War. In developing their estimate, Behrens, et al. (1992) review the estimates provided by U.S. General Accounting Office (1991b), Ravenal (1991), and Kaufmann and Steinbruner (1991).

Behrens, et al. (1992) summarize their analysis by concluding:

> The security cost of oil...is either insignificant or ponderous, depending upon the assumptions made. Counting only the military costs that would not have been incurred without a mission to protect oil flow from the Persian Gulf, and spreading those costs over total exports from the region, yields a cost of a few cents per barrel. On the other hand, if any military cost that can be seen to aid Gulf oil flow is counted, and the total is attributed only to Gulf oil imported to the United States, then a cost figure in the hundreds of dollars per barrel can be generated (page 32).

The authors also note that attempts to internalize these costs may not have a significant impact on reducing the costs. They conclude that attempts to reduce U.S.

dependence on imported oil will probably have little effect on the amount spent in the Persian Gulf.

3.9.4 Health and Environmental Impacts

The study focuses primarily on the value of the external effects from air pollution. These include human health, reduced crop yields, the decline of certain species in forests, effects on materials (e.g., erosion, discoloration) and visibility. Climate change is not included. The authors acknowledge that there will be damage to ecosystems resulting from oil spills, but believe that there are no "defendable estimates of the monetary value of the external costs associated with oil spills" (page 55).

Behrens et al. (1992) emphasize that "the effects on the environment and health...are imperfectly understood. And how these environmental and health damages can be approximated in monetary terms is controversial" (page 10).

On the basis of a literature review, the authors conclude that a "reasonable estimate of the lower-range of health and welfare damages results from transportation-related pollution is between $5 and $6 billion per year" (page 52).

3.10 MILLER AND MOFFET (1993)

3.10.1 Summary

Through a survey of existing literature, Miller and Moffet (1993) attempt to develop estimates of the full cost of transportation in the United States in 1990. In addition to estimating the costs associated with automobile transportation, they also estimate these costs for bus and rail transportation. Table 3.8 summarizes their estimates of the costs of automobile use.

They consider three categories of costs. "Personal costs," which include the costs to purchase, register, maintain and operate a car, are borne solely by the vehicle owner. "Government subsidies" include direct construction and maintenance expenditures plus other government expenses directly associated with providing transportation services. Miller and Moffet's (1993) estimate of these costs are net of user fees. For example, they estimate that the total annual road capital and operating expense in 1990 was $85.7 billion. When $21.5 billion in road user fees are deducted, they estimate that the net annual cost was about $64 billion. "Societal costs" include all other indirect costs, or what is often referred to as externalities. Examples of this include energy dependence, pollution, and congestion.

Miller and Moffet (1993) estimate that the full annual costs of automobile transportation were between $1.1 and $1.6 trillion in 1990. They estimate that $72 billion of this was government subsidies, between $310 and $592 billion were societal costs, and the remaining $775 to $930 billion were personal costs incurred by the vehicle owners. However, one must be cautious in interpreting their estimate of the full annual costs of automobile transportation. The bulk of this estimate is comprised of personal costs which are entirely borne by vehicle users, and it can be somewhat confusing when this figure is added to net government expenditures, rather then gross government expenditures. Total unpaid social costs, i.e. net government subsidies plus societal costs, totaled between $378 and $660 billion in 1990.

The largest cost components of the societal costs include air pollution and energy. Miller and Moffet (1993) estimate that air pollution cost between $120-$220 billion annually. These costs include impacts on human health, damages to agricultural products, reduced visibility, global warming and acid rain. They include air pollution resulting from vehicle manufacturing, fuel production, and road construction, as well as from vehicles. Energy costs are estimated to be between $45 and $150 billion. The low end includes indirect energy use, oil industry tax subsidies, and military expenditures to protect oil imports; the high end includes these, plus the macroeconomic impacts on the balance of trade.

All of the cost estimates are based on literature reviews.

3.11 KPMG PEAT MARWICK, STEVENSON AND KELLOGG (1993)

3.11.1 Summary

As part of a long range transport planning initiative, the Greater Vancouver Regional District and the Province of British Columbia (TRANSPORT 2021) hired Peat Marwick, Stevenson, and Kellogg to analyze the full costs of various modes of passenger transportation in British Columbia. “The study represents a snapshot of 1991. It estimates the total cost of transporting people in the Lower Mainland in that year and goes on to calculate the average cost ‘per unit’ of travel, by different modes, for urban peak, urban off-peak and suburban travel” (page iii). There are three specific goals of the analysis. First, estimate the total economic costs of different modes of passenger transport in the region. Second, determine how much is paid by users of the different transport modes and how much is paid by non-users. Third, provide a broad basis for assumptions and recommendations regarding the future levels and methods of pricing the movement of people in the region.

The authors utilize a computer model to estimate these costs for five different modes of private transport (average car, fuel efficient car, car pool, van pool, and motorcycle), four modes of public transport (diesel bus, trolley bus, SkyTrain, and SeaBus), and three modes of non-motorized transport (bicycle, pedestrian, and telecommuting). The costs are evaluated for travel in urban areas during peak and off-peak hours, as well as for suburban travel. They find that the total subsidy for automobile transport in 1991 was $2.7 billion Canadian dollars (C$2.7 billion).

The authors estimate that the total cost associated with the transportation in the Lower Mainland of British Columbia in 1991 was approximately C$13.6 billion. The five modes of transport via private motor vehicles accounted for C$11.7 billion (86%) of the total cost, and were subsidized approximately C$2.7 billion, or 23% of the total cost of private transport.

The costs of private motorized vehicles are summarized in Table 3.9. We discuss two of the largest costs below.

3.11.2 Cost of Personal Time

The cost of personal time accounts for almost one-third of the total transportation costs due to private motor vehicles. To derive this figure, the authors make three assumptions: first, that the average wage in British Columbia is C$18 per hour; second, that personal time is valued at 50% of the average wage for the driver and 35% of the average wage for passengers; third, that every trip is 13.5 kilometers. These assumptions are combined with estimates of average speeds, and vehicle occupancy during peak and off-peak hours to arrive at an estimated $3.8 billion in personal travel time costs.

3.11.3 Unaccounted Accidents

The largest social cost not borne entirely by users is unaccounted accidents (C$1.3 billion), which are accident costs that are not accounted for in insurance claim payments. They assume that the unit cost of an accident is C$3.04 million per fatality, C$114 thousand per non-fatal injury in a fatal accident, C$58.2 thousand per non-fatal injury in a non-fatal accident, and C$3.2 thousand in property damage to each vehicle in any accident. It appears that these values come from a literature review.

Using the results of other studies, the authors assume that the vehicle users incur 70% of the costs of accidents, business 10% of the costs, and society incurs remaining 20%. From this, they estimate that the automobile transportation subsidy that results from unaccounted accidents was about C$397 million in 1991.

3.12 CALIFORNIA ENERGY COMMISSION (1994)

3.12.1 Purpose

In the aftermath of the 1991 Persian Gulf War, the California Legislature passed, and Governor Pete Wilson signed into law Senate Bill 1214 (Killea), which provides, in part, that:

> The Legislature finds that...the overdependence on...petroleum based fuels as an energy source in the transportation sector is a threat to the energy security of the state, due to continuing market and supply uncertainties. In addition petroleum use...contributes substantially to the following public health and environmental problems: air pollution, acid rain, global warming, and the degradation of California's marine environment and fisheries. Therefore, it is the policy of this state to fully evaluate the economic and environmental costs of petroleum use...including the costs and value of environmental externalities, and to establish a state transportation energy policy that results in the least environmental and economic cost to the state (CEC, 1994, p.1).

The task of developing a "least environmental and economic cost scenario," including the costs and values of environmental externalities and energy security, was assigned to the California Energy Commission (CEC), as part of its biennial report. To fulfill this charge, the CEC analyzed the social costs and benefits of several state and national energy policies, relative to a base case. The policy measures included increasing fuel taxes, increasing fuel economy standards, and subsidizing the price of alternative fuels and vehicles. For each policy, the CEC estimated the differences in travel, emissions, fuel use, and so forth, relative to the base case. The value of the differences was the net social cost or benefit of the policy.

3.12.2 Estimates of avoidable costs

The CEC quantified several kinds of social costs: travel time, accidents, infrastructure maintenance and repair, governmental services, air pollution, carbon dioxide, petroleum spills, and energy security. The results of the CEC analysis are summarized in Table 3.10.

Travel time. The CEC uses the "Personal Vehicle Model," a demand forecasting model that projects vehicle stock, VMT, and fuel consumption for personal cars and trucks. They use this to estimate that congestion costs are $10.60/hour (1992$), including the disutility of aggravation. The CEC also estimates the actual net change in travel time in Los Angeles under the various policy scenarios.

Accidents. The cost of accidents is estimated by multiplying the cost per injury or death by the number of injuries or deaths, for several kinds of injuries. Dr. Ted Miller, lead author of the much-cited Urban Institute (1991) study of the cost of highway crashes, developed California-specific unit costs for the commission. The CEC uses the Urban Institute (1991) study to allocate costs to different vehicle classes.

Infrastructure maintenance and repair. The CEC estimates the cost of maintaining and repairing infrastructure on the basis of average annual expenditures over 1986-1990, as reported in FHWA's annual *Highway Statistics*. (The CEC does not estimate the cost of infrastructure construction, because it assumes that infrastructure is built at the same rate in all of the policy scenarios analyzed). A highway cost-allocation study done for the State of California is used to allocate total costs to vehicle classes.

Government services. In the CEC analysis, government services related to motor-vehicle use are highway-related administration, traffic law enforcement and safety, interest on debt and debt retirement associated with highway expenditures, and other local government expenditures, such as parking enforcement, other police costs (e.g., for car theft), and disposal of oil. The CEC uses Miller and Moffet's (1993) estimates of other local government expenditures, and FHWA's *Highway Statistics* data to estimate all of the rest.

Air pollution. To calculate the cost/mile of air pollution, the CEC multiplies the change in total emissions (estimated using California's mobile-source emission-inventory models, EMFAC and BURDEN), by the $/ton value of emissions, and then divides by the change in travel. The $/ton values, estimated for nitrogen oxides, sulfur oxides, reactive organic gases, particulate matter, and carbon monoxide, are from the Air Quality Valuation Model, a damage-function model that estimates the cost of air pollution from power plants in California air basins. The CEC acknowledges that damage values for power plants might not apply to motor vehicles.

Carbon dioxide. Because, according to the CEC, "reliable data on damage functions are not available ... the Energy Commission uses carbon emission control costs alone to represent carbon values" (CEC, 1994, p. 3G-1). The CEC adopted its own control-cost estimate of $28 / ton-carbon, from its 1990 Electricity report. To estimate the total CO_2 cost of different policies, the CEC multiplied the cost / ton by the change in carbon emissions under the different scenarios. Carbon emission rates for different fuelcycles were taken from reports by CEC, EPA, and DeLuchi et al. (1987).

Petroleum spills. After reviewing some of the literature on oil-spill damages, and discussing the extent to which such damages already are internalized, the CEC calculates the oil-spill externality by multiplying an estimate of the external cost of a worst-case spill (based on estimates of the cost of the Exxon Valdez spill) by the probability of a spill (based on estimate in an Environmental Impact Report for a marine terminal in California), and dividing by total petroleum-product output in California.

Energy security. The CEC reviews some of the voluminous literature on energy security, and discusses its applicability to California. On the basis of this review, the CEC concludes that oil dependency costs the State of California $0.1 to $1.0 per barrel of oil.

3.13 APOGEE RESEARCH (1994)

3.13.1 Summary

The report by Apogee Research (1994), prepared for the Conservation Law Foundation, presents the results of case studies of intra-urban passenger transportation in Boston, Massachusetts, and Portland, Maine, conducted in 1993. The report "attempts to develop a framework for comparing transportation costs and to provide specific quantification of the costs of passenger transportation" in the two regions analyzed. The benefits of transportation are not included in the analysis. The methodology developed by the authors was constructed such that it could be adapted for other case studies.

The study evaluates nine "sub-modes" of transportation: single-occupancy vehicles (SOVs) on expressways, SOVs off expressways, high-occupancy vehicles (HOVs) on expressways, HOVs off expressways, commuter rail, rail transit, bus, bike and walking. It also distinguishes between high, medium, and low population densities, and between on-peak and off-peak travel. Table 3.11 shows the cost categories in the Apogee (1994) report, and Table 3.12 summarizes their estimates, expressed in cents per passenger mile traveled (PMT).

Their report is divided into four main sections. The first is a comprehensive literature review which provides background information for the analytic framework. The next section describes the methodology used in the case studies, and defines the costs and travel parameters studied. The analytic framework is then applied to estimate the costs in Portland and Boston. Finally, the report presents the results of the case studies and suggests some policy responses.

Apogee Research (1994) focuses primarily on developing original estimates for user and governmental costs, and relies on existing estimates for the societal costs. Wherever possible, they try to use data from the relevant agencies to develop their cost estimates. This is supplemented by literature reviews when data were unavailable. The cost estimates derived from these data are primarily the result of relatively simple, yet intuitively reasonable, analysis, rather than the product of more complex and rigorous statistical models. The authors acknowledge this, stating that "while additional research and analysis on particular costs would undoubtedly lead to more refined results, we believe that these case studies provide a good sense of the magnitude of the various costs of transportation" (page 59).

The policy recommendations provided in the report are common to most analyses: reduce trip length, favor lower-cost modes, increase vehicle occupancy, explore single occupancy vehicle pricing, and educate the public on transportation costs.

In summary, the Apogee Research (1994) report provides an intuitive and relatively simple framework for estimating the costs of various modes of travel. For the most part, their estimates of government expenditures related to transportation are the result of original analysis of government data. Societal costs of transportation are primarily based on inferences drawn from existing studies. Table 3.12 provides a summary of the case study results for automobile travel during peak hours in high population density areas. The Apogee Research (1994) report also provides similar tables that summarize the results of the case studies for the other transportation modes considered (bus, bicycle, walking, commuter rail, and rail transit), population densities (medium-, and low-density), and for off peak travel.

3.14 LEE (1994)

3.14.1 Summary

This paper examines the debate about the extent to which drivers pay for the costs associated with motor-vehicle use. Lee (1994) uses a "full cost pricing" approach to analyze this issue. "Full cost pricing (FCP) is a policy strategy based on the idea that the economy would benefit from imposing discipline on each enterprise that all its costs should be recovered from consumers, i.e., total user revenues should equal total cost for each activity" (page 1).

Lee (1994) is concerned more with theoretical issues than with estimates of costs. After discussing the fundamental economic issues pertaining to full and marginal cost pricing, Lee (1994) outlines a strategy for estimating these costs. His focus is not so much on developing an actual cost estimate, instead he emphasizes the development of the appropriate structure for estimating these costs. He discusses which costs should be included in a social costs analysis, why they should be estimated, and important theoretical issues on how they should be calculated.

However, Lee (1994) does make some estimates of cost, apparently on the basis of a review of some of the literature. Table 3.13 summarizes his estimates.

3.15 COHEN (1994)

3.15.1 Summary

The goal of this study is to “update and extend the analysis of the external costs of highway operations that was reported in Appendix E of the Final Report on the 1982 Federal Highway Cost Allocation Study [FHWA, 1982]” (page 1). The present report actually is an interim report. It summarizes the literature on estimating external costs, assesses recent efforts to develop national estimates of these costs, and recommends procedures that should be used to develop cost models and estimate the monetary value of external costs.

When the final report is completed, it will contain three primary elements. First, it will provide estimates of the external costs due to congestion delay, highway crashes, noise, and air pollution. Second, the final report will include a simple computer model to reproduce these results in future analyses. Third, it will include a detailed discussion of institutional barriers, equity implications, and political consideration that affect marginal-cost pricing and other methods to charge highway users for external costs.

For the most part, the literature review in the interim report refers to studies that we have reviewed here. And, because this is an interim report, there are no actual cost estimates for us to report. However, it does appear that the authors are in the process of developing a useful framework for developing original estimates of these costs. Recent unpublished manuscripts from this project indicate that they are using external cost estimation methods similar to those summarized in Report #9 of Delucchi et al. (1996).

3.16 LITMAN (1996)

3.16.1 Summary

The purpose of Litman’s (1996) analysis is to establish a foundation for analyzing transportation costs. After estimating the costs for the United States in 1994, primarily through an extensive literature review, he discusses the implications of these costs with respect to efficiency, equity, land use, stakeholder perspectives and future policy options.

Litman (1996) classifies transportation costs into three dichotomies: internal (users) or external (social), market or non-market, and fixed or variable. The costs associated with each classification are listed in Table 3.14.

Litman (1996) estimates the costs associated with these categories for eleven different modes of transportation: average car, fuel-efficient car, electric car, van, rideshare passenger, diesel bus, electric bus/trolley, motorcycle, bicycle, walk, and telecommute. In order to estimate the costs, Litman (1996) conducts a literature review, and from this information, generates his “best guess” at the true cost.

The value of user time alone accounts for over 20% of the total cost of the average automobile used during peak times in urban areas. As a basis for deriving the costs, Litman (1996) uses a 1992 value of time schedule for British Columbia because it is "current and comprehensive." That study assumes that the value of the personal vehicle driver's time is 50% of the current average wage, which Litman assumes to be $12.00. He calculates total costs assuming average speeds of 30 mph (urban peak), 35 mph (urban off-peak), and 40 mph (rural), and an hourly cost premium of 16.5% in congestion.

In Litman's (1996) study, land-use impacts and parking costs are the largest external costs associated with an average car. On the basis of a review of the literature, he assumes that the average automobile off-street parking cost is around three dollars per day.

According to Litman (1996), "a primary conclusion of this research is that a major portion of transportation costs are external, fixed, or non-market...This underpricing leads to transportation patterns that are economically inefficient and inequitable..." (page vi).

Table 3.15 summarizes Litman's (1996) results. It should be noted that Litman's estimates are based on especially comprehensive literature reviews.

3.17 LEVINSON ET AL. (1996)

3.17.1 Goals and Methodology

The goal of this report is to compare the costs of intercity passenger travel by air, automobile and high-speed rail in the "California Corridor" (i.e. between San Francisco and Los Angeles). The policy question which they seek to address is whether the full costs of developing a high-speed rail line are comparable to the costs of expanding the air or highway transportation systems. To accomplish this, they develop long- and short-run average and marginal cost functions for each of the three modes of travel. Our discussion of this report will be limited to their analysis of the highway costs.

They identify three types of costs associated with automobile use: infrastructure costs, user costs and social (or external) costs.[5] For the most part, Levinson, et al. (1996) develop their own econometric models to estimate these costs. Each of these is discussed in more detail below. A summary of their estimates of the long-run full costs of the highway system is provided in Table 3.16.

3.17.2 Infrastructure Costs

Infrastructure costs include the capital costs of infrastructure construction and debt servicing, and operations and maintenance costs. They develop an econometric model which predicts total expenditures as a function of the price of inputs (interest

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[5] Note that Levinson, et al. (1996) use a different definition of social costs than we do in our analyses. In their report, they limit the definition of social costs to negative externalities, or external costs.

rates, wage rates, and material costs), outputs (miles traveled per passenger vehicle, single unit truck, and combination truck), and network variables (the length of the network, and the average width of the links). The data used for the model come from a variety of sources, such as FHWA data on maintenance and operating costs, and Gillen, et al (1994) data on capital stock, among others. Costs are allocated among the different vehicle classes using engineering data to derive the amount of damage caused by each vehicle type.

3.17.3 User Costs

Levinson et al. (1996) estimate the cost of gas, oil, maintenance, tires, and depreciation for an intermediate-size automobile, the most popular vehicle type in 1995. (They omit insurance costs, license and registration fees and taxes on the grounds that they are transfers). Most of their data are taken from the American Automobile Association (AAA), with the exception of a simple regression they ran to estimate depreciation. For depreciation, they regressed the posted price on an Internet classified ad for Ford Taurus and Honda Accord against the age of the vehicle and the distance traveled times the vehicle age. From this, they estimate depreciation costs of $1351 per year and 2.3 cents per vehicle mile traveled. They assume 10,000 miles per year, which translates to an annual depreciation of about $1581, as compared to the AAA estimate of $2883 in 1993.[6]

The authors assume that the user time cost is 10 cents per passenger kilometer traveled (pkt), ignoring congestion costs. This is based on assuming an average speed of 100 kmh with time value of $10 per hour. Assuming 1.5 passengers per vehicle, this translates to 15 cents per pkt.

3.17.4 External Costs

Levinson et al. (1996) identify four external costs (which they also refer to as social costs): (1) accidents, (2) congestion, (3) noise, (4) air pollution. In the economics literature, these are also known as negative externalities. Their estimates for each of these costs is based on an analysis of existing work.

Their estimate of accident costs is developed by combining an accident rate model by Sullivan and Hsu (1988) with the work of the Urban Institute (1991). The accident cost is obtained by determining the value of life, property, and injury per accident, and multiplying this by an equation which represents accident rates. They estimate that a crash on a rural interstate costs about $120,000 (in 1995 dollars), and a crash on an urban interstate costs about $70,000. The disparity is largely attributable to the higher death rate associated with accidents on rural highways due to the higher speed of travel.

Assuming a modest average traffic flow of 1500 vehicles per hour per lane, a $10 per hour value of time, and 1.5 passengers per vehicle, the authors estimate that the

[6] We note that they regressed asking price, not transaction price, did not distinguish sub-models, and did not consider other variables, such as options, that affect sales price.

average congestion costs are $0.005 per pkt. This is based on a simple analysis of the relationship between traffic volumes and time delay.

For noise costs, they develop a simple analytical framework and use the results of previous research to derive their estimates. Essentially, this involved translating noise production rates into economic damages using total residential property damage costs per linear kilometer of roadway.

In this study, the authors identify four types of air pollution (photochemical smog, acid deposition, ozone depletion, and global warming), which generate three types of damages (health effects, material and vegetation effects, and global effects). Their estimate of the total cost of air pollution is derived by combining the results of a number of other studies.

3.17.5 Costs Excluded from the Analysis

Levinson et al. (1996) do not include US defense expenditures in the Middle East or the costs of parking in their analysis. They dispute the notion that a significant share of US defense expenditures are directly related to the transportation sector. Parking costs are excluded because their research is limited to analyzing intercity transportation, and the authors assume that parking is a local cost that is unlikely to be avoided by switching intercity travel modes.

3.18 DELUCCHI ET AL. (1996)

Delucchi et al. (1996) estimate the annualized social cost of motor-vehicle use, as:

- 1990-1991 periodic or "operating" costs, such as fuel, vehicle maintenance, highway maintenance, salaries of police officers, travel-time, noise, injuries from accidents, and disease from air pollution;

plus

- the 1990-91 value of all capital, such as highways, parking lots, and residential garages (items that provide a stream of services), converted (annualized) into an equivalent stream of annual costs over the life of the capital.

Thus, their annualization approach essentially is an investment analysis, or project evaluation.

They classify and estimate costs in six general categories: personal nonmonetary costs, motor vehicle goods and services priced in the private sector, motor-vehicle goods and services bundled in the private sector, motor-vehicle goods and service provided by government, monetary externalities, and non-monetary externalities.

3.18.1 Personal non-monetary costs

In Delucchi et al. (1996), personal non-monetary costs are those unpriced costs of motor-vehicle use that a person imposes on him or herself as a result of the decision to travel. The largest personal costs of motor-vehicle use are personal travel time in uncongested conditions and the risk of getting into an accident that involves nobody else. Delucchi et al. (1996) perform detailed analyses of travel time costs in this category.

3.18.2 Motor-vehicles goods and services priced in the private sector.

The economic cost of motor-vehicle goods and services supplied in private markets is the area under the private supply curve: the dollar value of the resources that a private market allocates to supplying vehicles, fuel, parts, insurance, and so on. To estimate this area, Delucchi et al. (1996) subtract producer surplus (revenue in excess of economic cost) and taxes and fees (mainly non-cost transfers) from total price-times-quantity revenues. The cost items in this category include those in the "transportation" accounts of the GNP, and several others. For several of these costs, Delucchi et al (1996) use the same primary data and methods used in GNP accounting.

3.18.3 Motor-vehicle goods and services bundled in the private sector.

Some very large costs of motor-vehicle use are not explicitly priced as separate costs of motor-vehicle use. Foremost among these are the cost of free non-residential parking, the cost of home garages, and the cost of local roads provided by private developers. However, all of these costs are included in the price of "packages," such as houses and goods, that are explicitly pried[7]. Delucchi et al. (1996) use a variety of primary data sources to estimate national parking and garage costs.

3.18.4 Motor-vehicle goods and services provided by the public sector.

Government provides a wide range of infrastructure and services in support of motor-vehicle use. The most costly item is the capital of the highway infrastructure. Delucchi et al. (1996) analyze survey data from FHWA, the Bureau of the Census, the Department of Energy, Department of Justice, and other government departments to estimate these infrastructure and service costs. They note that, whereas all government expenditures on highways and the highway patrol are a cost of motor-vehicle use, only a portion of total government expenditures on local police, fire, corrections, jails, and so on, is a cost of motor-vehicle use.

3.18.5 Monetary externalities.

Some costs of motor-vehicle use actually are valued monetarily yet are unpriced from the perspective of the responsible motor-vehicle user, and hence are external costs. Examples of these are accident costs that are paid for by those *not* responsible for the accident, and congestion that displaces monetarily compensated work. Delucchi et al. (1996) estimate that the largest monetary externalities are those resulting from travel delay.

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[7]Delucchi et al. (1996) note that this bundling is not necessarily inefficient: in principle, a producer will bundle a cost, and not price it separately, if the administrative, operational, and customer (or employee) cost of collecting a separate price exceed the benefits.

3.18.6 Nonmonetary externalities.

Delucchi et al. (1996) follow Baumol and Oates (1988) and define a non-monetary externality as a cost or benefit imposed on person A by person B but not accounted for by person B. Environmental pollution, traffic delay, and uncompensated pain and suffering due to accidents are common examples of externalities.

Environmental costs include those related to air pollution, global warming, water pollution, and noise due to motor vehicles. Delucchi et al. (1996) use damage functions to estimate air pollution costs and noise costs. They find that by far the largest environmental externality is the cost of particulate air pollution.

The estimates of Delucchi et al. (1996) of the total social costs in each of the six cost categories are summarized in Table 3.17.

3.19 OTHER STUDIES RELATED TO THE SOCIAL COST OF MOTOR-VEHICLE USE: BRIEF REVIEWS

3.19.1 Hart (1985, 1986)[8]

Hart reviews the automobile-related expenditures for the City of Pasadena, California, in order to determine whether there is a significant shortfall between costs and revenues associated with motor vehicle use. He attributes all of the budget of the public works department, and all of the cost of debt service and capital projects, to motor-vehicle use. He also allocates to motor-vehicle use 33% of the city prosecutor’s budget, on the basis of interviews with the prosecutor; 13.8% of the fire department budget and 16.4% of paramedic expenditures, on the basis of a weighted average of the number of calls in 1981; 39.9% of the total police budget, on the basis of the amount of time that officers were involved in different motor-vehicle related activities; and 13.45% of administrative overhead (city council, city manager, etc.), on the basis of the city’s analysis of administrative expenditures. By his estimates, these auto-related expenditures in Pasadena totaled $15.7 million in fiscal year 1982-83.

The motorist contribution towards these costs, estimated as “city shares of the fuel tax and the in-lieu tax (license fee), parking charges, parking and traffic fines, and miscellaneous smaller taxes levied on trailers and trucks” (page 3), was only $3.9 million, resulting in a shortfall of $11.8 million, or more than 75% of expenditures.

Hart’s (1985, 1986) analysis of the city budget provides a reasonable estimate of the costs of motor-vehicle use in Pasadena. But Hart (1985, 1986) goes further, and states that “if Pasadena is not atypical, the nationwide subsidy derived from local government is $60 billion annually or about 2% of the gross national product” (page 9). However, we doubt that it is meaningful to extrapolate from one small city to the entire United States. This point is important because Hart’s extrapolation from Pasadena to the whole country has been cited in other studies of social costs (e.g., MacKenzie, et al., 1992).

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[8] Hart (1986) is a published summary of the more detailed but unpublished 1985 analysis.

3.19.2 The Royal Commission on National Passenger Transportation (1992)

The Royal Commission on National Passenger Transportation (1992) estimates infrastructure, environmental, accident, vehicle, and tax and fee costs paid by users and others, for travel by car, bus, plane, train, and ferry, in Canada, in the year 2000. The purpose of the study was to "inquire into and report upon a national integrated intercity passenger transportation system to meet the needs of Canada and Canadians in the 21st century" (page 1).

3.19.3 Pucher (1993a, 1993b) and Beshers (1994)

Beshers' (1994) paper is rejoinder to a pair of 1993 papers by John Pucher (1993a, 1993b). Pucher's first paper is a short literature review of studies already referenced in this chapter and does not contribute any insights which have not already been discussed elsewhere. Pucher's second paper focuses on policy prescriptions to mitigate the unpaid social costs of vehicle use.

Beshers (1994) critiques the policy prescriptions presented by Pucher (1993a, 1993b), but does not attempt to quantify the costs associated with vehicle use. Beshers (1994) acknowledges that there are environmental and social impacts which result from vehicle use which might warrant government action, and agrees with Pucher (1993a, 1993b) that market-based incentives, rather than regulations, are the preferred means of correcting this. However, Beshers (1994) disagrees with Pucher (1993a, 1993b) regarding the preferred market-based instruments which should be implemented. According to Beshers (1994), Pucher (1993a, 1993b) emphasizes a major fuel tax increase, as well as supplementary parking charges and congestion pricing. However, Beshers (1994) believes that this approach over-emphasizes the need to reduce automobile travel and disregards the "enormous social benefits" that automobile use provides.

Beshers (1994) arranges the costs identified by Pucher (1993a, 1993b) into three categories of his own. The first category includes items that Pucher (1993a, 1993b) believes are external costs, and which therefore should be internalized by pricing, but that Beshers (1994) believes are not external costs, and therefore not in need of fixing. For example, based on Federal Highway Administration statistics, Pucher (1993a, 1993b) estimates that only 60% of the government expenditures on highway construction and maintenance are covered by user fees. However, Beshers (1994) believes that this estimate is too low, and that it is more likely that user fees cover closer to 99% of the costs. Beshers (1994) believes that Pucher's (1993a, 1993b) estimates incorrectly count bond retirement and interest as costs, and incorrectly fail to count as user payments the 2.5 cents/gallon tax for deficit reduction, $8.3 billion in property taxes and assessments, other taxes and fees targeted to beneficiaries of highway improvements, and $4.3 billion in general sales tax revenue attributable to vehicle and fuel purchases.

Beshers (1994) also believes that free and "underpriced" parking at work and stores is priced correctly, and is not a subsidy[9] to vehicle users. He assumes that employer-paid parking and free parking at stores are the result of free markets in which employers and merchants believe that free parking must be offered in order to remain competitive. Therefore, in Beshers view, and contrary to Pucher's (1993a, 1993b) arguments, there is no need for government intervention to eliminate parking subsidies[10].

Beshers' (1994) second category includes costs that Pucher (1993a, 1993b) identifies as external costs, and which Beshers agrees are external costs but in markets that are not *directly* related to motor-vehicle use. Accident costs are an example. Beshers (1994) believes that the external costs of accidents are due to failures in insurance regulations and in the tort system. Hence, Beshers argues that the appropriate prescription is to reform the insurance and justice system, rather than, say, tax gasoline or travel.

The final category includes costs that Beshers (1994) agrees are externalities directly of motor-vehicle use (as Beshers puts it, for which vehicle use is the "central issue"): air pollution, congestion and urban sprawl. Beshers believes that these cannot be adequately addressed by a fuel tax, and concurs with Pucher (1993a, 1993b) that, for example, congestion pricing is the appropriate response to congestion. However, he argues that the nature of the external costs of urban sprawl is unclear and that therefore it is not clear how one should account for these costs.

In summary, Beshers (1994) criticizes Pucher's (1993a, 1993b) policy recommendations of fuel taxes and parking surcharges because these instruments do not operate directly on the sources of the external costs[11].

3.19.4 Dougher (1995)

Dougher (1995) compares government expenditures on the highways with payments by road users. Her data on expenditures and payments are taken from the FHWA's *Highway Statistics* data, except that she adds her own detailed estimates of sales-tax and property-tax payments related to motor-vehicle use. Because she expands

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[9] Beshers defines a subsidy as a transfer of funds from the government to vehicle users.

[10] Beshers does acknowledge that the $155 per month in free parking that is not subject to federal income taxes does represent a subsidy, which probably should be eliminated.

[11] Economic theory tells us that the optimal policy prescription for an externality is a Pigouvian tax which acts directly on the source of the externality. Any tax that attempts to address the externality, but fails to act directly on the source (e.g. taxing fuels to reduce air pollution) is inferior to the optimal tax (which would be an emission tax in the case of air pollution) because it is economically inefficient. In the case of the external costs of noise, for example, Beshers (1994) observes that the most desirable approach would be to "use noise monitors combined with transponder license plates to record decibel levels from all vehicles in sensitive areas...[to] allow the imposition of an appropriately graduated decibel tax." While this is certainly true in theory, the practical difficulties associated with implementing such a tax suggest that other alternatives probably should be explored.

the definition of "road-user payment" to include general sales taxes and property taxes, but does not expand the estimates of expenditures beyond those in the FHWA report, she finds a surplus of payments over costs. We note, though, that one just as well may count general sales taxes and property taxes as payments for general government services, rather than as payments for highway services in particular.

Morris and DeCicco (1996) critique Dougher's estimates.

3.19.5 Green (1995)

Green (1995) does not make any new estimates of costs, but rather reviews and reconstructs the existing estimates (from some of the studies reviewed above, and from some not included above) according to what he believes are sensible principles of free-market accounting and pricing. These principles, however, are not derived from or necessarily consistent with economic theory, and as a result Green's is not really a re-estimate of economic costs, or a discussion of economic efficiency, but rather an ideological interpretation of the existing literature.

3.19.6 Qin et al. (1996)

Qin et al. (1996) have developed a model, called "MODECOST," that can be used to estimate the full social costs of automobiles, buses, and rail systems, in specific corridors or larger networks. The interactive, menu-driven model estimates costs per passenger mile, total costs, and average costs for the three different modes. For automobiles, the model includes roadway facility costs, external costs (congestion, accident costs, air pollution costs, and "others"), and personal vehicle costs. The authors use cost values from the existing literature.

3.19.7 DeCicco and Morris (1996)

DeCicco and Morris (1996) review the literature on social costs, and estimate total social costs of automobile and transit use in Wisconsin. They discuss where the region is headed, and alternatives, such as transit-oriented development plus "more equitable pricing and financing" that they believe will lead to lower costs.

3.19.8 Transportation Research Board (TRB) (1996)

The TRB study is a preliminary examination of the marginal social costs of moving freight by road, rail, and water. It is intended "not to provide definitive answers as to whether shippers pay their full social costs but rather to determine the feasibility of making such estimates" (p. 1). In the TRB study, the total social cost is the sum of vehicle costs, infrastructure costs, and external costs (congestion, accident, air-pollution, petroleum-consumption, and noise costs).TRB discusses the appropriate methods for estimating external costs and infrastructure subsidies, and then provides estimates for four specific cases: i) short haul movement of grain from Minnesota to a Mississippi River port, by interstate highway or rail; ii) long-haul movement of grain from Minnesota to New Orleans by rail and barge; iii) container movement from Los Angeles to Chicago by truck or rail; and iv) truck delivery of groceries in Hartford, Connecticut. Although the cost calculations are based on a relatively brief review of the literature, they are explicit and easy to follow and generally conceptually reasonable.

3.19.8 Other sources of estimates of the social-cost of motor-vehicle

1). Textbooks in urban economics usually contain excellent theoretical and conceptual discussions of the private and external costs of urban transport, and of related issues such as optimal road pricing. In this context, they often summarize and even extend estimates of the social cost. See, for example Straszheim (1979), Heilbrun (1981), and Mills and Hamilton (1984), all of whom refer to the early seminal work of Keeler and Small (1975).

2) Many studies apply estimates of social cost as part of a policy or econometric analysis (e.g., DRI / McGraw Hill, 1994), or as part of cost-benefit analysis or least-cost planning (e.g., FHWA, 1995).

3). There are many studies of individual cost areas, such as air pollution. The conference proceedings edited by Greene et al. (1997) includes chapters with state-of-the-art estimates of air-pollution costs, congestion costs, accident costs, and parking costs. Small and Kazimi (1995) provide another recent estimate of the cost of motor-vehicle air pollution.

4). The Federal Railroad Administration (1993a, 1993b) lists and categorizes the external and social costs of transportation, in large fold-out charts, and cites a few cost estimates.

5). Report #20 of Delucchi et al. (1996) provides a bibliography of a wide range of data sources relevant to estimating the social cost of motor-vehicle use.

3.19.9 Studies of the social cost of motor-vehicle use in Europe

There are a number of studies of the social cost of motor vehicle use in Europe. Quinet (1997) provides the most comprehensive and up-to-date summary of European studies of the external cost of traffic noise. The range of cost estimates in Quinet expressed as a percentage of GDP, is:

Noise	Local pollution	Accidents
0.02 to 2.0%	0.03 to 1.0%	1.1 to 2.6%

Verhoef (1994) also summarizes many estimates of the external cost of noise (0.02% to 0.2% of GDP), air pollution (0.1% to 1.0% of GDP), and accidents (0.5% to 2.5% of GDP) attributable to road traffic, and Kageson (1992) and Ecoplan (1992) summarize estimates of the damage cost of air pollution caused by the transport sector (0.01% to 1.0% of GDP). These ranges indicate that European estimates of air pollution and accident costs are somewhat lower than ours (see Delucchi et al., 1996).

Several recent, detailed studies are not included in the reviews by Quinet (1997), Verhoef (1994), or Kageson (1992). Bickel and Friedrich (1995, 1996) use a damage-function approach to estimate the external costs of accidents, air pollution, noise, land use, and "dissociation effects" (e.g., roads as barriers or dividers in communities) of passenger vehicles, freight trucks, passenger rail, and freight rail in Germany in 1990.

Otterson (1995) uses a detailed damage-function approach, similar to the method of Delucchi et al. (1996; see Report #9), to estimate the external cost of the effect of traffic emissions on health, crops, materials, forests, and global warming, in Finland in 1990. Maddison et al. (1996; summarized in Maddison, 1996) use a variety of methods to estimate the marginal external costs of global warming, air pollution, noise, congestion, road damage, and accidents attributable to road transport in the United Kingdom in 1993. Eyre et al. (1997) estimate the effects of fuel and location on the damage cost of transport emissions. And Mayeres et al. (1996) develop marginal-cost functions, again similar to those of Delucchi (1996; see Report #9), to estimate the marginal external cost of congestion, accidents, air pollution, and noise, attributable to cars, buses, trams, metro rail, and trucks, in the urban area of Brussels in the year 2005.

3.19.10 A note on studies of the external cost of electricity generation

Until recently, there was considerably more work on the social cost of electricity use than on the social cost of motor-vehicle use, in part because it was easier to model the electricity system than the private transportation system. The state of knowledge through 1990 was reviewed comprehensively by Pace University (1990), which estimated the following external costs, in 1989 cents/kwh generated:

	Coal	Oil	Gas	Nuclear	Solar
Air pollution (SO_2, NO_X, PM, CO_2)	3-7	3-8	1	0	0
Accidents and decommissioning	0	0	0	3	0
Total (including other)	*3-7*	*3-8*	*1*	*3*	*0-1*

In the same year, Hohmeyer (1990) presented the results of a comprehensive analysis of the social cost of electricity generation in Germany. The results were broadly similar to those of Pace University (1990).

Recently, a large team of U.S. and European experts have made detailed, original estimates of the external costs of the electricity-generation fuelcycle for several specific kinds of power plants (e.g., a conventional steam coal-burning plant in Lauffen, Germany). This is by the far the most sophisticated modeling effort to date, although it is not necessarily the most comprehensive (for example, global warming damages are not estimated). The U. S. and European analyses have been published in several volumes[12], and summarized by Lee (1996), and Eyre and Holland (1996). Lee (1996) also compares the results of the U. S. analyses with the results of the earlier Pace University work cited above. In general, the recent U. S. and European fuelcycle studies estimate

[12]The U. S. study, *Estimating Externalities of Fuel Cycles,* is documented in a series of reports produced by Oak Ridge National Laboratory and Resources for the Future, and published by McGraw Hill/Utility Data Institute, Washington, D. C. The European study, *Externalities of Fuel Cycles, "ExternE" Project,* is documented in several reports published by the European Commission, DGXII, Science, Research and Development, JOULE.

several-fold lower external costs per kwh than did Pace University (1990) and Hohmeyer (1990).

3.20 SUMMARY AND CONCLUSION

The next-to-last series of tables, 3.18a to 3.18d, present our qualitative assessment of the degree of originality and detail of each major cost estimate in each of the studies.

3.20.1 Our rating of degree of originality

In Tables 3.18a to 3.18d, we give each cost estimate a rating of A through F. The ratings, which are explained in Table 3.19, are our assessments of the degree of originality and to some extent detail behind each of the estimates in each of studies reviewed. They are not necessarily assessments of the overall quality; after all, there is nothing wrong with a literature review, and a more original estimate is not necessarily a better estimate. An original estimate, which we rate as an “A,” might be done well or poorly, and might even be inferior to an “D” estimate, which is a citation from another study.

Certainly, there is a fair bit of judgment in our assessment here. What one person might consider an original analysis, another might consider a detailed literature review. Although naturally we tried to assess the studies consistently and evenhandedly, we recommend that readers consult the original studies to fully understand the level of originality and detail.

3.20.2 Conclusion

A review of the study summaries, in Tables 3.1 to 3.17, indicates that in most cost categories, there is a very wide range of estimates. As stated in the introduction, the differences in the estimates is due to differences in accounting systems, analytical methods, assumptions, and data sources.

This review, and the ratings of Tables 3.18a-3.18d, indicate that many of the current estimates are based on literature reviews rather than detailed analysis. Of course, this in itself is not necessarily bad. The real problems are: 1) many of the reviews rely on outdated, superficial, non-generalizable, or otherwise inappropriate studies; and 2) many of the cost-accounting systems are not fully articulated, or else are a mix economic and equity criteria. Thus, with few exceptions (e.g., Delucchi et al, 1996), the recent literature on national social costs in the U. S., taken at face value, is of limited use.

There is, however, a good deal of excellent work focusing on particular costs or localities, and it is to these, rather than generic summaries, that analysts should turn. For example, there now are two or three detailed, original, and conceptually correct analyses of air pollution costs in the U. S. (Delucchi et al., 1996, Report #7; Krupnick et al., 1997; Small and Kazimi [for Los Angeles], 1995). These analyses supersede previous work. Similarly, the noise-cost estimates of Delucchi et al. (1996; Report #14) supersede the older and heretofore widely cited estimates of Fuller et al. (1983). The estimates of government-service costs in Delucchi et al. (1996; Report #7) supersede the few earlier piecemeal estimates. The recent volume edited by Greene et al. (1997) summarizes state-of-the art estimates of accident costs, congestion costs, travel-time costs, air pollution costs, and parking costs.

3.21 REFERENCES

3.21.1 Studies reviewed or referenced in this paper

Apogee Research, Inc., *The Costs of Transportation: Final Report*, Conservation Law Foundation, Boston, MA, March (1994).

C. E. Behrens, J. E. Blodgett, M. R. Lee, J. L. Moore, L. Parker, *External Costs of Oil Used in Transportation*, 92-574 ENR, Congressional Research Service, Environment and Natural Resources Policy Division, Washington, D. C., June (1992).

E. W. Beshers, *External Costs of Automobile Travel and Appropriate Policy Responses*, Highway Users Federation, Washington, D. C., March 9 (1994).

P. Bickel and R. Friedrich, "External Costs of Transport in Germany," in *Social Costs and Sustainability: Valuation and Implementation in the Energy and Transport Sector*, ed. by O. Hohmeyer, R. L. Ottinger and K. Rennings, Springer-Verlag, Berlin, Germany, pp. 341-356 (1996).

P. Bickel and R. Friedrich, *External Costs of Transport in Germany*, Institut fur Energiewirtshcaft und Rationelle Energieanwendung (IER), Universitat, Stuttgart, Germany (1995).

California Energy Commission, *1993-1994 California Transportation Energy Analysis Report*, P300-94-002, Draft Staff Report and Technical Appendices, Sacramento, California, February (1994).

H. Cohen, *Incorporation of External Cost Considerations in Highway Cost Allocation*, Interim Report, BAT-93-009, Federal Highway Administration, Washington, D. C. September (1994).

COWIconsult, *Monetary Valuation of Transport Environmental Impact — the Case of Air Pollution*, Danish Ministry of Energy, The Energy Research Programme for Transport, Lyngby, Denmark, December (1991).

J. DeCicco and H. Morris, *The Costs of Transportation in Southeastern Wisconsin*, draft report, American Council for an Energy Efficient Economy, Washington, D. C., June (1996).

M. A. Delucchi et al., *The Annualized Social Cost of Motor-Vehicle Use in the United States, based on 1990-1991 Data*, UCD-ITS-RR-96-3, in 20 reports, Institute of Transportation Studies, University of California, Davis, December (1996).

DRI / McGraw-Hill, *Transportation Sector Subsidies; U. S. Case Studies*, U. S. Environmental Protection Agency, Energy Policy Branch, Washington, D. C., November (1994).

R. S. Dougher, *Estimates of Annual Road User Payments Versus Annual Road Expenditures*, Research Study #078, American Petroleum Institute, Washington, D. C., March (1995).

Ecoplan, *Damage Costs of Air Pollution, A Survey of Existing Estimates*, T&E 93 / 1, European Federation for Transport and the Environment, Brussels, Belgium, December (1992).

N. J. Eyre, E. Ozdemiroglu, D. W. Pearce, and P. Steele, "Fuel and Location Effects on the Damage Costs of Transport Emissions," *Journal of Transport Economics and Policy*, January: 5-24 (1997).

N. Eyre and M. Holland, "External Costs of Fossil Fuel Cycles," in *Social Costs and Sustainability: Valuation and Implementation in the Energy and Transport Sector*, ed. by O. Hohmeyer, R. L. Ottinger and K. Rennings, Springer-Verlag, Berlin, Germany, pp. 121-136 (1996).

Federal Highway Administration, *Final Report on the Federal Highway Cost Allocation Study*, U. S. Department of Transportation, Washington, D. C., May (1982)

Federal Highway Administration, Office of the Environment and Planning, *Evaluation of Transportation Alternatives*, Report No. 6, U. S. Department of Transportation, Washington, D. C., September (1995).

Federal Railroad Administration, Office of Policy, "Social Costs of Transportation Systems," U. S. Department of Transportation, Washington, D. C., August (1993a).

Federal Railroad Administration, Office of Policy, "Environmental Externalities of Transportation Systems," U. S. Department of Transportation, Washington, D. C., August (1993b).

J. W. Fuller, J. B. Hokanson, J Haugaard, J. Stoner, *Measurements of Highway Interference Costs and Air Pollution and Noise Damage Costs*, Final Report 34, U.S. Department of Transportation, Federal Highway Administration, Washington, D. C, May (1983).

J. Gifford, "Toward the 21st Century," *The Wilson Quarterly*, Volume XVII, Number 1, pp. 40-47, Winter (1993).

K. Green, *Defending Automobility: A Critical Examination of the Environmental and Social Costs of Auto Use,* Policy Study No. 198, Reason Foundation, Los Angeles, California, December (1995).

D. L. Greene, D. W. Jones, and M. A. Delucchi, editors, *Measuring the Full Social Costs and Benefits of Transportation,* Springer-Verlag, Heidelberg, Germany (1997).

M. Hanson, "Automobile Subsidies and Land Use, Estimates and Policy Responses," *Journal of American Planning Association,* **58**(2):60-71, Winter (1992).

S. Hart, *An Assessment of the Municipal Costs of Automobile Use,* December 24, (1985).

S. Hart, "Huge City Subsidies for Autos, Trucks," *California Transit,* September (1986).

J. Heilbrun, *Urban Economics and Public Policy,* second edition, St. Martin's Press, New York (1981).

O. Hohmeyer, "Social Costs of Electricity Generation: Wind and Photovoltaic Versus Fossil and Nuclear," *Contemporary Policy Issues* **VIII**: 255-282 (1990).

P. S. Hu and J. Young, *Summary of Travel Trends, 1990 Nationwide Personal Transportation Survey,* FHWA-PL-92-027, Office of Highway Information and Management, Federal Highway Administration, U. S. Department of Transportation, Washington, D. C., March (1992).

P. Kageson, *External Costs of Air Pollution, the Case of European Transport,* T&E 92/7, European Federation for Transport and the Environment, Brussels, Belgium, December (1992).

A. Kanafani, *The Social Costs of Road Transport, A Review of Road Traffic Noise, Air Pollution and Accidents, Institute of Transportation Studies,* University of California, Berkeley, December (1983).

T. Keeler and K. A. Small, *The Full Costs of Urban Transport,* part III, "Automobile Costs and Final Intermodal Comparisons," monograph 21, Institute of Urban and Regional Development, University of California, Berkeley, July (1975).

B. Ketcham and C. Komanoff, *Win-Win Transportation, A No-Losers Approach to Financing Transport in New York City and the Region,* draft, Transportation Alternatives, New York City, July (1992).

KPMG Peat Marwick Stevenson & Kellogg, Management Consultants, *The Cost of Transporting People in the Lower British Columbia Mainland*, prepared for Transport 2021, Burnaby, British Columbia, Canada, March (1993).

A. J. Krupnick, R. D. Rowe, and C. M. Lang, "Transportation and Air Pollution: the Environmental Damages," in *Measuring the Full Social Costs and Benefits of Transportation*, ed. by D. L. Greene, D. Jones, and M. A. Delucchi, Springer-Verlag, Heidelberg, Germany, pp. 337-370 (1997).

D. B. Lee, *Full Cost Pricing of Highways*, draft, U.S. Department of Transportation, Research and Special Programs Administration, Cambridge, MA, November (1994).

R. Lee, "Externalities Studies: Why Are the Numbers Different?," in *Social Costs and Sustainability: Valuation and Implementation in the Energy and Transport Sector*, ed. by O. Hohmeyer, R. L. Ottinger and K. Rennings, Springer-Verlag, Berlin, Germany, pp. 13-28 (1996).

D. Levinson, D. Gillen, A. Kanafani, J.M. Mathieu, *The Full Cost of Intercity Transportation - A Comparison of High Speed Rail, Air and Highway Transportation in California*, UCB-ITS-RR-96-3, Institute of Transportation Studies, University of California at Berkeley, Berkeley, CA, June (1996).

D. Levinson, D. Gillen, A. Kanafani, *The Social Costs of Intercity Transportation: A Review and Comparison of Air and Highway*, Institute of Transportation Studies, University of California at Berkeley, Berkeley, CA, September 26 (1996). Submitted for possible publication in *Transport Reviews*.

T. Litman, *Transportation Cost Analysis: Techniques, Estimates and Implications*, Victoria Transport Policy Institute, British Columbia, July 16 (1996).

B. Lockyer and B. Hill, Rebuttal to Argument Against Proposition 157 (Toll Roads and Highways, Legislative Constitutional Amendment), California November 1992 Election Ballot Pamphlet, California Legislative Analysts Office, Sacramento, California (1992).

J. J. MacKenzie, R. C. Dower, D. D. T. Chen, *The Going Rate: What it Really Costs to Drive*, World Resources Institute, Washington, D. C, June (1992).

D. Maddison, "The True Cost of Road Transport in the United Kingdom," in *Social Costs and Sustainability: Valuation and Implementation in the Energy and Transport Sector*, ed. by O. Hohmeyer, R. L. Ottinger and K. Rennings, Springer-Verlag, Berlin, Germany, pp. 357-379 (1996).

D. Maddison, O. Johansson, E. Calthrop, D. W. Pearce, T. Litman and E. Verhoef, *The True Cost of Road Transport*, Blueprint #5, CSERGE, Earthscan, London, England (1996).

I. Mayeres, S. Ochelen and S. Proost, "The Marginal External Costs of Urban Transport," *Transportation Research D* **1D**: 111-130 (1996).

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

E. S. Mills and B. W. Hamilton, *Urban Economics*, third edition, Scott, Foresman, and Company, Glenview, Illinois (1984).

H. Morris and J. DeCicco, *A Critical Review of API's Estimates of Road User Payments and Expenditures*, American Council for an Energy Efficient Economy, Washington, D. C., July (1996).

T. Otterstrom, *Valuation of the Impacts from Road Traffic Fuel Emissions, Summary of Results and Conclusions*, MOBILE207Y, Ekono Energy Ltd., Helsinki, Finland February (1995).

National Research Council, *Automotive Fuel Economy: How Far Should We Go?*, National Academy Press, Washington, D. C. (1992).

Pace University Center for Environmental Legal Studies, *Environmental Costs of Electricity* , Oceana Publications, New York (1990).

J. Pucher, "Social and Environmental Costs of Automobile Driving," *Passenger Transport*, November 8 (1993a).

J. Pucher, "Strategies for Raising the Price of Auto Use to Reflect Its Full Cost," *Passenger Transport*, November 15 (1993b).

J. Qin, J. Weissman, M. A. Euritt and M. Martello, "Evaluating the Full Costs of Urban Passenger Transportation", Paper 961131, presented at *Transportation Research Board 75th Annual Meeting*, Washington, D. C., January 7-11 (1996).

E. Quinet, "Full Social Costs of Transportation in Europe," in *Measuring the Full Social Costs and Benefits of Transportation*, ed. by D. L. Greene, D. Jones, and M. A. Delucchi, Springer-Verlag, Heidelberg, Germany, pp. 69-112 (1997).

Royal Commission on National Passenger Transportation, *Directions, The Final Report of the Royal Commission on National Passenger Transportation, Summary,* Minister of Supply and Services, Ottawa, Canada (1992).

K. A. Small, “Estimating the Air Pollution Costs of Transport Modes,” *Journal of Transport Economics and Policy*, **11**:109-133, May (1977).

K. A. Small and C. Kazimi, “On the Costs of Air Pollution from Motor Vehicles,” *Journal of Transport Economics and Policy* **29**: 7-32 (1995).

M. R. Straszheim, “Assessing the Social Costs of Urban Transportation Technologies,” in *Current Issues in Urban Economics*, ed. by P. Mieszkowski and M. Straszhiem, The John Hopkins University Press, Baltimore, Maryland, pp. 196-232 (1979).

Transportation Research Board, Committee for Study of Public Policy for Surface Freight Transportation, *Paying Our Way: Estimating Marginal Social Costs of Freight Transportation*, Special Report 246, National Research Council, Washington, D. C. (1996).

E. Verhoef, “External Effects and Social Costs of Road Transport,” *Transportation Research A* **28A**: 273-287 (1994).

3.21.2 Studies referenced in the papers reviewed and mentioned here

Association for Commuter Transportation and the Municipality of Metropolitan Seattle, *Proceedings of the Commuter Parking Symposium*, Seattle, December 6-7 (1990).

W. J. Baumol and W. E. Oates, *The Theory of Environmental Policy*, second edition, Cambridge University Press, New York, (1988).

R. Cervero, “Jobs-Housing Balance and Regional Mobility,” *Journal of the American Planning Association*, **55**(2):136-150.

M. A. DeLuchi, R. A. Johnston, and D. Sperling, *Transportation Fuels and the Greenhouse Effect*, UERG-180, University Energy Research Group, University of California, Berkeley, December (1987). 80 pp.

Eno Transportation Foundation, Inc., *Transportation in America*, 9th ed., September (1991).

E. Folkerts-Landau, “The Social Cost of Imported Oil,” *The Energy Journal*, 5(3), July (1984).

L. G. Hines, *The Market, Energy, and the Environment*, Allyn and Bacon, Boston (1988).

B. Hokanson, M. Minkoff, and S. Cowart, *Measures of Noise Damage Costs Attributable to Motor Vehicle Travel*, Technical Report 135, Institute of Urban and Regional Research, The University of Iowa, Iowa City, August (1981).

D. W. Jorgenson and P. J Wilcoxen, “Reducing U.S. Carbon Dioxide Emissions: the Cost of Different Goals,” CSIA Discussion Paper 91-9, Kennedy School of Government, Harvard University, October (1991).

W. W. Kaufmann and J. D. Steinbruner, *Decisions for Defense Prospects for a New Order*, The Brookings Institution, Washington, DC (1991).

T. E. Keeler, G. S. Cluff, and K. A. Small, *On the Average Costs of Automobile Transportation in the San Francisco Bay Area*, unpublished paper, Institute of Urban and Regional Development, University of California, Berkeley, Berkeley, CA (1974)

T. E. Keeler and K. A. Small, *On the Environmental Costs of the Various Transportation Modes*, unpublished paper, Institute of Urban and Regional Development, University of California, Berkeley, Berkeley, CA (1974)

Kihlberg and Tharp, *Accident Rates as Related to Design Elements of Rural Highways*, National Cooperative Highway Research Program Report #47, Highway Research Board, Washington, D. C. (1968).

L. B. Lave and E. P. Seskin, “Air Pollution and Human Health,” *Science*, **169** :723-733, August (1970).

A. D. May, Jr., “Economics of Operation on Limited-Access Highways,” *Highway Research Board Bulletin*, 107:49-62 (1955).

Midwest Research Institute, *Systems Analysis of the Effects of Air Pollution on Materials*, Prepared for the U.S. National Air Pollution Control Administration, Revised Edition (1970).

D. M. Murray and U. F. W. Ernst, *An Economic Assessment of the Environmental Impact of Highway Deicing*, EPA-600/2-76-105, Environmental Protection Agency, Washington, D. C. (1976).

J. Meyer, J. Kain, M. Wohl, *The Urban Transportation Problem*, Harvard University Press, Cambridge, MA (1965)

A. E. Pisarski, *Commuting in America*, Eno Foundation for Transportation, Washington, D. C. (1987).

E. C. Ravenal, *Designing Defense For a New World Order*, The Cato Institute, Washington, D. C. (1991).

D. Rice, *Estimating the Cost of Illness*, P. H. S Publication No. 947-6, U.S. Public Health Service (1966).

E. C. Sullivan and C-I. Hsu, *Accident Rates Along Congested Freeways*, UCB-ITS-RR-88-6, Institute of Transportation Studies, University of California, Berkeley (1988).

Texas Transportation Institute in cooperation with the U.S. Federal Highway Administration, *Roadway Congestion in Major Urbanized Areas 1982-1987*, (1987)

M. A. Toman, "The Economics of Energy Security: Theory, Evidence, Policy." ENR 91-13, Resources for the Future, Washington, DC, April (1991).

Urban Institute, *The Costs of Highway Crashes*, FHWA-RD-91-055, Federal Highway Administration, U. S. Department of Transportation, Washington, D. C., June (1991).

U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics 1989*, FHWA-PL-90-003, U.S. Government Printing Office, Washington, D. C. (1990).

U.S. General Accounting Office, *Traffic Congestion, Trends, Measures, and Effects*, GAO / PEMD-90-1, Washington, D. C. (1990).

U.S. General Accounting Office, *Smart Highways: An Assessment of their Potential to Improve Travel*, GAO / PEMD-91-18, Washington, D. C. May (1991a).

U. S. General Accounting Office, *Southwest Asia: Cost of Protecting U.S. Interests*, GAO / NSIAD-91-250, Washington, D. C., August (1991b).

Wilbur Smith and Associates, *Parking in the City Center*, Wilbur Smith and Associates, New Haven (1965).

TABLE 3.1. SAMPLE CALCULATION FOR A ONE-WAY, PEAK-HOUR AUTO WORK TRIP (TWELVE-MILE LINE-HAUL TRIP, 1972$ PER CAR-TRIP) (KEELER AND SMALL, 1975)

Assumptions	
Interest Rate	12%
Time value per person per hour	$3 in vehicle
Trip length	
Urban-suburban freeway	8 miles
Central city freeway	4 miles
Suburban arterial	2 miles
in central business district	0.75 miles
Persons per auto	1.5
Auto type	subcompact

Cost Category	**Residential Collection**	**Line-Haul**	**Downtown Distribution**
Public costs	0.023	1.759	0.335
Time costs	0.637	1.080	1.295
Direct operating costs	0.093	0.401	0.035
Auto capital costs	0.045	0.272	0.017
Accident costs	0.076	0.200	0.028
Parking costs			2.145
Subtotals	*0.874*	*3.712*	*3.855*
Total cost per vehicle trip	**8.44**		
Total cost per passenger trip	**5.63**		

Source: Keeler and Small (1975), Table 18, page 104.

TABLE 3.2. EFFICIENT USER CHARGES FOR AUTOMOBILES IN 1981 (CENTS PER VEHICLE MILE TRAVELED) (FHWA, 1982)

Components of Efficient Prices	Location	
	Rural	**Urban**
Pavement Repair		
Vibration Damages to Vehicles		
Highway Administration and Services	0.3	0.7
Excess Delay / Congestion	0.3	11.2
Accidents		
Increased Vehicle Operating Costs		
Air Pollution		1.5
Water Pollution		
Noise		0.1
Visual Intrusion		
Danger to Non-Users and Property		
Total Efficient User Charges	*0.6*	*13.5*
Existing Average User Fees	*1.3*	*1.7*
Profit (Loss)	*0.7*	*(11.8)*

Source: FHWA (1982), page E-53.

TABLE 3.3. SOCIAL COST ESTIMATES IN THE UNITED STATES (KANAFANI, 1983)[a]

	Total Cost (10^9 $)	**Average Cost** (Cents per VMT)	**Percent of GDP**
Noise	1.3 - 2.6	0.1 - 0.2	0.06 - 0.12%
Air Pollution	3.2 - 9.7	up to 0.62[b]	0.14 - 0.36%
Accidents	33.0 - 37.0	2.4 - 2.7	2.0 - 2.4%

Source: Kanafani (1983), pages 7, 9, 11.

[a] Kanafani's estimates are from earlier studies, with a range of base-year dollar estimates. The dollar estimates have *not* been adjusted to a single base-year.

[b] Kanafani does not report cost / mile corresponding to the low-end total cost.

TABLE 3.4. 1989 ANNUAL SOCIAL COST OF VEHICLE USE NOT BORNE BY DRIVERS (BILLIONS OF 1989 DOLLARS) (MACKENZIE ET AL., 1992)

Market Costs	**$ Billion**
Highway Construction and Repair	13.3
Highway Maintenance	7.9
Highway Services (Police, Fire, etc.)	68.0
Value of Free Parking	85.0
Total Market Costs	*174.2*
External Costs	
Air Pollution	10.0
Greenhouse Gases	27.0
Strategic Petroleum Reserve	0.3
Military Expenditures	25.0
Accidents	55.0
Noise	9.0
Total External Costs	*126.3*
Total Social Costs	*300.5*

Source: MacKenzie, et al. (1992).

TABLE 3.5. 1990 COSTS OF ROADWAY TRANSPORTATION IN THE UNITED STATES (BILLIONS OF 1990 DOLLARS) (KETCHAM AND KOMANOFF, 1992)

Direct Costs of Roadway Transportation Borne by Users	**$ Billion**
Personal Transportation (Auto)	510.8
Taxi / Limousine Services	7.5
School Bus Transport	7.5
Freight Movement by Truck	272.6
Roadway Construction and Maintenance	48.1
Off-street Parking	not estimated
Total Direct Costs of Roadway Modes (A) [a]	*798.4*
Direct Costs of Roadway Transport Borne by Non-users	**$ Billion**
Roadway Construction, Maintenance, Admin. Services	16
Parking	not estimated
Total Direct Costs Not Borne by Users (B)	*16*
Externality Costs Borne by Users	**$ Billion**
Congestion Costs	142.8
Air Pollution Health and Property Costs	1.5
Accident Costs	290.4
Noise Costs	1.1
Pavement Damage to Vehicles	15
Total Externality Costs Borne by Motorists (C)	*450.8*
Externality Costs Borne by Non-users	**$ Billion**
Congestion Costs	25.2
Air Pollution Health and Property Costs	28.5
Accident Costs	72.6
Noise Costs	21.1
Vibration Damage to Buildings and Infrastructure	6.6
Land Costs	66.1
Security Costs	33.4
Climate Change	25
Total Externality Costs Borne by Non-Users (D)	*278.5*
Total Cost of Roadway Transport (A+B+C+D)	*1544*
Direct Cost of Roadway Transport (A+B)	*814*
External Cost of Roadway Transport (C+D)	*729*

Roadway Costs Borne by Everyone (B+D)	*295*

Source: Ketcham and Komanoff (1992), page 20.

[a] It is unclear why Ketcham and Komanoff (1992) did not include the cost of "Roadway Construction and Maintenance" in this total. It probably was an oversight. In any case, we report the totals in our table as they are shown in the original source.

TABLE 3.6. HIGHWAY SUBSIDIES FOR MADISON, WISCONSIN IN 1983 (THOUSANDS OF 1983 DOLLARS) (HANSON, 1992)

Cost Item	**Total Subsidy**
Direct costs	
Highway Construction	3,899
Highway Maintenance	2,441
Highway Infrastructure, Other	1,627
Traffic Police	3,743
Indirect costs, externalities	
Air Pollution	5,200
Water Pollution	600
Accidents - Personal Injury	12,536
Accidents - Property Damage	
Accidents - Lost Earnings	1,586
Land Use Opportunity Cost	1,000
Petroleum Subsidy	1,800
Total	*34,432*

Source: Hanson (1992), page 65.

TABLE 3.7. ESTIMATED EXTERNAL COSTS OF OIL USED IN TRANSPORT (BILLIONS OF DOLLARS) (BEHRENS ET AL., 1992)

Cost Category	Low	High
Risk of Supply Disruption	3.2	4.9
Monopsony Effects	11.3	13.0
Military Expenditures	0.3	5.0
Air Pollution - Human Health	3.6	3.6
Air Pollution - Crop Damages	1.1	1.1
Air Pollution - Material Damages	0.3	0.3
Air Pollution - Visibility	0.8	0.8
Oil Spills	n. e.	n. e.
Total with monopsony effects [a]	*10.5*	*17.0*
Total without monopsony effects [a]	*21.8*	*30.0*

Source: Behrens, et al. (1992), page 4. n.e. = not estimated.

[a]The estimates in each category and the totals shown here are those reported in Behrens, et al. (1992). Behrens et al. based their estimates for individual categories on a review of the literature. They did not convert the dollar estimates in the literature to single dollar base year. The totals are the overall estimates of Behrens et al., not the sum of the individual estimates.

TABLE 3.8. THE FULL COST OF TRANSPORTATION IN THE UNITED STATES IN 1990 (BILLIONS OF 1990 DOLLARS) (MILLER AND MOFFET, 1993)

Personal Costs	**$ Billion**
Ownership and Maintenance	775 - 930
Government Subsidies	
Capital and Operating Expenses	64.0
Local Government Expenses	8.0
Total Government Subsidies	*72.0*
Societal Costs	
Energy Dependence	45 - 150
Congestion	11.0
Parking	25 - 100
Accidents	98.0
Noise	2.7 - 4.4
Building Damage	0.3
Air Pollution	120 - 220
Water Pollution	3.8
Total Societal Costs	*310 - 592*
Unquantified Costs	
Wetlands Lost	n. e.
Agricultural Land Lost	n. e.
Damage to Historic Property	n. e.
Changes in Property Value	n. e.
Equity Effects	n. e.
Urban Sprawl	n. e.
Total Government and Societal Costs	*378 - 660*
Total Costs	*1,153 - 1,590*

Source: Miller and Moffet (1993), page 66. n.e. = not estimated.

TABLE 3.9. SOCIAL COSTS OF PRIVATE MOTORIZED VEHICLES IN THE LOWER MAINLAND OF BRITISH COLUMBIA (MILLIONS OF 1991 CANADIAN DOLLARS) (KPMG 1993)

Cost Category	Total Cost C$ Million	Subsidy [a] C$ Million	Percent Subsidy
Road land value	601	601	100%
Air, noise and water pollution	515	515	100%
Road Construction	416	416	100%
Unaccounted accident costs	1,324	397	30%
Urban sprawl	343	282	82%
Parking (commercial and government)	157	157	100%
Road maintenance	145	144	100%
Commercial delays	97	97	100%
Protection services	45	45	100%
Operating Cost	3,847	0	0%
Personal Time	3,804	0	0%
Residential Parking	453	0	0%
Total Social Costs	*11,746*	*2,654*	*23%*

Source: KPMG, (1993), page 29 and Appendix C, page 19.

[a]KPMG (1993) estimated amount of the subsidy for each category on the basis of their assumptions regarding the incidence of each type of cost.

TABLE 3.10. AVOIDABLE COSTS OF MOTOR-VEHICLE USE IN CALIFORNIA (CALIFORNIA ENERGY COMMISSION, 1994)

Cost category	**"Avoidable" cost**
Congestion	$0.005-$0.008 / mile (Los Angeles only, in 2010, 1992$)
Accidents	LDVs: $0.12 / mi in 1990
	Buses: $0.26 / mi in 1990
Highway maintenance and repair	LDVs: $0.006 / mi (1990$)
	Buses: $0.013 / mi (1990$)
Service	$0.011 / mi (1990$)
Air pollutants	$0.012-$0.014 / mi
Carbon dioxide	valued at $28 / ton-carbon (1989$)
Petroleum spills	$0.132 / bbl in 2010
Energy security	$0.1 to $1.0 / bbl

Source: CEC (1994). Note that the values here, which are from the Technical Appendices, are similar but not identical to the values shown in the CEC's Table 4.1.

TABLE 3.11. TRANSPORTATION COSTS USED IN APOGEE RESEARCH (1994) CASE STUDIES

User Costs [a]	Governmental Costs [b]	Societal Costs [c]
Vehicle Purchase and Debt	Capital Investment - land, structures, vehicles	Parking - Free Private
Gas, Oil, Tires [d]	Operations and Maintenance	Pollution - health care, cost of control, productivity loss, environmental harm
Repairs, Parts	Driver Education and DMV	Private Infrastructure Repair - vibration damage, etc.
Auto Rentals	Police, Justice, and Fire	Accidents - health insurance, productivity loss, pain and suffering
Auto Insurance	Parking - public, tax breaks	Energy - trade effects
Tolls [d]	Energy - security	Noise
Transit Fares [d]	Accidents - public assistance	Land Loss - urban, crop value, wetlands
Registration, Licensing and Annual Taxes [d]	Pollution - public assistance	Property Values and Aesthetics
Parking - paid		Induced Land Use Patterns
Parking - housing cost		
Accidents - private expense		
Travel Time		

Source: Apogee Research (1994), page 38. DMV = department of motor vehicles.

[a] User costs are the costs borne by vehicle owners: the direct ownership and operating costs, such as gas, oil and parts; the indirect costs, such as garage parking, and accident risks.

[b] Governmental costs include government expenditures that are not explicitly for the purpose of transportation, but which nevertheless are necessitated by vehicle travel.

[c] Societal cost of transportation are those paid by neither the traveler nor the government, but rather are spread across the economy.

[d] These items are, or include, dedicated taxes that fund governmental transportation expenditures and which must be deducted from costs in column 2.

TABLE 3.12. 1993 COSTS OF MOTOR VEHICLE USE FOR PEAK HOUR TRAVEL IN HIGH POPULATION DENSITY AREAS ($/PMT) (APOGEE RESEARCH, 1994)

Boston MA	**Single Occupancy Vehicle**		**High Occupancy Vehicle**	
Cost Type	*Expressway*	*Non-Expressway*	*Expressway*	*Non-Expressway*
User	0.88	1.07	0.50	0.69
Net Government[a]	0.05	0.10	0.03	0.05
Societal	0.12	0.17	0.05	0.08
Total	*1.05*	*1.34*	*0.58*	*0.82*
Portland ME	**Single Occupancy Vehicle**		**High Occupancy Vehicle**	
Cost Type	*Expressway*	*Non-Expressway*	*Expressway*	*Non-Expressway*
User	0.60	0.71	0.31	0.42
Net Government[a]	0.04	0.06	0.02	0.04
Societal	0.13	0.17	0.06	0.08
Total	*0.78*	*0.94*	*0.39*	*0.54*

Source: Apogee Research (1994), Appendix 2, pages 181-182, 185-187. $/PMT = dollars per passenger mile traveled.

[a]Net of user payments.

TABLE 3.13. ESTIMATES OF HIGHWAY COSTS NOT RECOVERED FROM USERS IN 1991 (BILLIONS OF DOLLARS) (LEE, 1994)

Cost Group	Cost Item	$ Billion
Highway Capital	Land (interest)	74.7
	Construction, Capital Expenditures	42.5
	Construction, Interest	26.3
	Land Acquisition and Clearance	n.e.
	Relocation of Prior Uses and Residents	n.e.
	Neighborhood Disruption	n.e.
	Removal of Wetlands, Aquifer Recharge	n.e.
	Uncontrolled Construction Noise, Dust, Runoff	n.e.
	Heat Island Effect	n.e.
Highway Maint.	Pavement, Right-of-Way, and Structures	20.4
Administration	Administration and Research	6.9
	Traffic Police	7.8
Parking	Commuting	52.9
	Shopping, Recreation, Services	14.9
	Environmental Degradation	n.e.
Vehicle Ownership	Disposal of Scrapped of Abandoned Vehicles	0.7
Vehicle Operation	Pollution from Tires	3.0
	Pollution from Used Oil and Lubricants	0.5
	Pollution from Toxic Materials	0.0
Fuel and Oil	Strategic Petroleum Reserve	4.4
	Tax Subsidies to Production	9.0
Accidental Loss	Government Compensation for Natural Disaster	n.e.
	Public Medical Costs	8.5
	Uncompensated Losses	5.9
Pollution	Air	43.4
	Water	10.9
	Noise and Vibration	6.4
	Noise Barriers	5.1
Social Overhead	Local Fuel Tax Exemptions	4.3
	Federal Gasohol Exemption	1.2
	Federal Corporate Income Tax	3.4
	State Government Sales Taxes	13.2
	Local Government Property Taxes	16.0
	Total Cost	*382.1*
	Current User Revenues	*52.1*
	Profit (Loss)	*(330.0)*

Source: Lee (1994), page 12. n.e. = not estimated. Maint. = maintenance.

TABLE 3.14. MOTOR VEHICLE TRANSPORTATION COSTS IDENTIFIED IN LITMAN (1996)

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

Source: Litman (1996), page 1-5.

TABLE 3.15. 1994 MOTOR VEHICLE COSTS IN THE UNITED STATES (BILLIONS OF 1994 DOLLARS) (LITMAN, 1996)

	Internal Costs	**External Costs**	***Total Costs***
Urban Peak	327	281	*607*
Urban Off-Peak	653	313	*966*
Rural	589	184	*773*
Total	*1,569*	*778*	*2,347*

Source: Litman (1996), page 4-6.

TABLE 3.16. LONG-RUN FULL COSTS OF THE HIGHWAY SYSTEM ($/VEHICLE-KM) (LEVINSON ET AL., 1996)

Cost Category	Short-Run Costs		Long-Run Costs	
	Marginal	Average	Marginal	Average
Infrastructure Costs				
Construction and Maintenance	0.0055	0.0008	0.0180	0.0174
External Costs				
Accidents	0.0350	0.0310	0.0350	0.0310
Congestion	0.0330	0.0680	0.0330	0.0068
Noise	0.0090	0.0060	0.0090	0.0060
Pollution	0.0046	0.0046	0.0046	0.0046
Total External Costs	*0.0816*	*0.1096*	*0.0816*	*0.0484*
User Costs				
Fixed + Variable	0.0490	0.1300	0.0490	0.1300
Time	0.5000	0.5000	0.1500	0.1500
Total User Costs	*0.5490*	*0.6300*	*0.1990*	*0.2800*
Total Costs [a]	***0.2861***	***0.3292***	***0.2986***	***0.3458***

Source: Levinson, et al. (1996), Table 5. 5-1, page 4-43.

[a] Note that the total costs for the short-run costs do not add up correctly. This table is reproduced directly from Levinson, et al. (1996) without changes.

TABLE 3.17. SUMMARY OF THE COSTS OF MOTOR-VEHICLE USE, 1990-91 (BILLIONS OF 1991$) (DELUCCHI ET AL., 1996)

	(billion $)		(percent)	
	Low	*High*	*Low*	*High*
(1) Personal nonmonetary costs of motor-vehicle use	$584	$861	30%	26%
(2) Motor-vehicle goods and services priced in the private sector (estimated net of producer surplus, taxes, fees)	$761	$918	40%	28%
(3) Motor-vehicle goods and services bundled in the private sector	$131	$279	7%	8%
(4) Motor-vehicle infrastructure and services provided by the public sector[a]	$122	$201	6%	6%
(5) Monetary externalities of motor-vehicle use	$55	$144	3%	4%
(6) Nonmonetary externalities of motor-vehicle use	$267	$885	14%	27%
Grand total social cost of highway transportation	**$1,920**	**$3,289**	**100%**	**100%**
Subtotal: monetary cost only (2+3+4+5)	$1,069	$1,543		

Source: Delucchi et al. (1996), Report #1.

TABLE 3.18A. SUMMARY OF SOCIAL COST ITEMS AND DEGREE OF ORIGINALITY IN THE STUDIES REVIEWED

Section in this paper	3.2	3.3	3.4	3.5
Author	Keeler and Small (1975)	FHWA (1982)	Kanafani (1983)	Fuller et al. (1983)
Geographic Region		USA	USA	USA
Year of Estimates		1981	varies	1976-79
Cost Categories[a]				
Accidents	B	F	C	A1/B
Air Pollution	A1/B	B	C	A1/B
Congestion / Time	A1	B		A1/B
Energy Dependence[b]				
Equity				
Global Warming / Climate Change				
Military Expenditures				
Noise Pollution	A1/B	B	C	A1
Parking	C			
Pavement Damage to Vehicles		E		
Roadway Construction	A1/A2			
Roadway Maintenance	A1/A2	A2		
Highway Services[c]	A1	C		
Strategic Petroleum Reserve				
Urban Sprawl / Land Use				
Vehicle Ownership and Operation		F		
Vibration Damage to Buildings				
Water Pollution		F		

FHWA = Federal Highway Administration. The ratings A through F are defined in Table 3.20.

[a]This list of cost categories is not meant to be all-inclusive. Instead, it represents some of the costs the are commonly estimated in these studies. The category definitions in this table necessarily are generic, because each study uses its own specific definitions. It is possible that some of the studies include other costs that are not identified in this table.

[b]Energy dependence may include such costs as macroeconomic effects of monopsony power, threats of supply disruption, trade effects, and petroleum subsidies.

[c]Highway services includes such costs as police services, fire-protection services, the justice system, and paramedics.

TABLE 3.18B. SUMMARY OF SOCIAL COST ITEMS AND DEGREE OF ORIGINALITY IN THE STUDIES REVIEWED

Section in this paper	3.6	3.7	3.8	3.9
Author	MacKenzie et al. (1992)	Ketcham and Komanoff (1992)	Hanson (1992)	Behrens, et al. (1992)
Geographic Region	USA	USA	Madison WI	USA
Year of Estimates	1989	1990	1983	varies
Cost Categories				
Accidents	D	D	D	
Air Pollution	C	D, C	C	C
Congestion / Time	C	D		
Energy Dependence			D	C
Equity				
Global Warming / Climate Change	C	D		F
Military Expenditures	D	D		C
Noise Pollution	D	D		
Parking	D			
Pavement Damage to Vehicles		D		
Roadway Construction	A2	D	A2	
Roadway Maintenance	A2	D	A2	
Highway Services	D/E	D	A2	
Strategic Petroleum Reserve	D	D		C
Urban Sprawl / Land Use			B	
Vehicle Ownership and Operation	D	D		
Vibration Damage to Buildings	E	D		
Water Pollution			D	

See the notes to Table 3.18a.

TABLE 3.18C. SUMMARY OF SOCIAL COST ITEMS AND DEGREE OF ORIGINALITY IN THE STUDIES REVIEWED

Section in this paper	3.10	3.11	3.12	3.13	3.14
Author	Miller and Moffet (1993)	KPMG (1993)	CEC (1994)	Apogee (1994)	Lee (1994)
Geographic Region	USA	B. C.	Cal-ifornia	Boston; Maine	USA
Year of Estimates	1990	1991		1993	1991
Cost Categories					
Accidents	B / C	A1 / B	B	B	C
Air Pollution	B	B	B	B	C
Congestion / Time	C	A1 / B	A1 / B	B / D	
Energy Dependence	C		C	D	
Equity	F				
Global Warming / Climate Change	C	B	D		
Military Expenditures	C				
Noise Pollution	C	A1 / A2		D	C
Parking	C	A1 / A2		A1	C
Pavement Damage to Vehicles					
Roadway Construction	A2	A2		A2	B
Roadway Maintenance	A2	A2	A2	A2	C
Highway Services	D	A2 / E	D	A2	C
Strategic Petroleum Reserve	C				C
Urban Sprawl / Land Use	F	E			F
Vehicle Ownership and Operation	D	B		A1 / B	C
Vibration Damage to Buildings	D				
Water Pollution	B	D	B / C		C

See the notes to Table 3.18a.

TABLE 3.18D. SUMMARY OF SOCIAL COST ITEMS AND DEGREE OF ORIGINALITY IN THE STUDIES REVIEWED

Section in this paper	3.15	3.16	3.17	3.18
Author	Cohen (1994)[a]	Litman (1996)	Levinson et al. (1996)	Delucchi et al. (1996)
Geographic Region	USA	USA	California	USA
Year of Estimates		1994		1990 / 1991
Cost Categories				
Accidents	F (A1 / B)	B / C	A1 / B	A1 / B
Air Pollution	F (A1 / B)	C	B	A1
Congestion / Time	F (A1)	B	B	A1
Energy Dependence		C		A1 / B
Equity		E		
Global Warming / Climate Change				A1 / B
Military Expenditures			F	B / E
Noise Pollution	F (A1)	C	B	A1
Parking		B / C	F	A1
Pavement Damage to Vehicles				
Roadway Construction		C	A1 / A2	A2
Roadway Maintenance		C	A1 / A2	A2
Highway Services		C		A1
Strategic Petroleum Reserve				A1
Urban Sprawl / Land Use		E		F
Vehicle Ownership and Operation		C	B	A1
Vibration Damage to Buildings				
Water Pollution		C		C

See the notes to Table 3.18a.

[a]Cohen (1994) is an interim report, not a completed project; the ratings in parentheses refer to expected degree of originality of final estimates when the research is completed.

TABLE 3.19. THE RATING SYSTEM

A1: Estimate based on detailed, original analysis of primary data
This designation was used if the author performed a detailed, original analysis based mainly on primary data, or developed detailed cost models, such as damage-function models of the cost of air pollution. Primary data include, but are not limited to: original censuses and surveys of population, employment and wages, government expenditures, manufacturing, production and consumption of goods and services, travel, energy use, and crime; financial statistics collected by government agencies, such as the Internal Revenue Service and state motor-vehicle departments; measured environmental data, such as of ambient air quality and visibility; surveys and inventories of physical infrastructure, such as housing stock and roads; and the results of empirical statistical analyses, such as epidemiological analyses of air pollution and health. Several of the analyses of in Delucchi et al. (1996) are in this category.
A2: Estimate based on straightforward analysis of primary data
This designation was used if the author made relatively straightforward use of primary (or “raw”) data published by a government agency. An example of this which appears in many studies is the use of Federal Highway Administration data (e.g., FHWA, 1990) to estimate highway construction and maintenance costs. (See above for other examples of primary data). *Difference between A1 and A2 ratings:* A1 work is more detailed and extensive than is A2 work.
B: Estimate based on a combination of original data analysis and literature review.
This designation was used if the author took published estimates and then adjusted them by changing some of the variables used to derive the estimates, or if the author combined published results from various sources to develop his own estimate. For example, in the FHWA Cost Allocation Study (FHWA, 1982), the authors estimate the costs of air pollution by combining vehicle pollutants emission rates published by the USEPA with an estimate of air pollution damage cost rates for each pollutant. *Difference between A2 and B ratings:* A2 work is based mainly on primary data, such as from government surveys or data series or physical measurements; whereas B work is more dependent on the secondary literature. However, the calculations in B work can be more extensive than those in A2 work, which can involve direct use of relevant primary data.

TABLE 3.19. THE RATING SYSTEM, CONTINUED

C: Estimate based on a review and analysis of the literature
This designation was used if the estimate was based on a review and analysis of literature, with perhaps some simple calculations. Some studies, such as Kanafani (1983), simply provide tables listing the results of other studies. Other studies, such as Behrens, et al. (1992) and Litman (1996), conduct a literature review and then make their own estimate on the basis of the review.   *Difference between B and C ratings:* B work involves some primary data (e.g., data from government surveys, or from physical measurements, or primary economic analyses), whereas C work does not; correspondingly, B work requires more calculation than C work.
D: Estimate is a simple extrapolation, adjustment, or citation from another study
This designation was used if the author did some simple manipulation or update of a previously published result. For example, in estimating congestion costs, Ketcham and Komanoff (1992) adjusted the FHWA's (1982) congestion factors to reflect 1990 data. Similarly, MacKenzie, et al. (1992) cite the results of a study by the Urban Institute (1991). They do adjust the constant dollar year to 1989, but makes no significant adjustment to the published estimate.   *Difference between C and D ratings:* C work involves more sources, and more analysis, than does D work.
E: Estimate is based mainly on supposition or judgment
This designation was used for estimates or simple, illustrative calculations based ultimately on supposition or judgment. For example, Ketcham and Komanoff's (1992) found no reliable estimates of vibration damage to buildings, and so used their judgment to develop their own.   *Difference between D and E ratings:* D work cites a substantive analysis or estimate of the cost under consideration; E work is based on judgment without reference to any direct estimate of the cost or its major components.
F: Cost item is discussed, but not estimated
This designation was used for those costs which the authors acknowledge as important, but do not attempt to quantify. For example, Lee (1994) discusses, but does not estimate, the costs of vehicle use. Miller and Moffet (1993) provide estimates for most costs, but do not estimate others due to insufficient data.