Title

MOTOR-VEHICLE INFRASTRUCTURE AND SERVICES PROVIDED BY THE PUBLIC SECTOR Report #7 in the series: The Annualized Social Cost of Motor-Vehicle Use in the United States, based on 1990-1991 Data

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Report #7 in the series: *The Annualized Social Cost of Motor-Vehicle Use in the United States, based on 1990-1991 Data*

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DRAFT REPORT FOR REVIEW. MAY BE CITED.

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DRAFT FOR REVIEW

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LIST OF ACRONYMS AND ABBREVIATIONS AND OTHER NAMES

The following are used throughout all the 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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7. MOTOR-VEHICLE INFRASTRUCTURE AND SERVICES PROVIDED BY THE PUBLIC SECTOR

7.1 INTRODUCTION

7.1.1 Background

Every year, federal, state, and local governments in the U. S. spend tens of billions of dollars to build and maintain roads, enforce traffic laws, put out motor-vehicle fires, lock up motor-vehicle criminals, control motor-vehicle pollution, research new motor fuels and motor-vehicle technologies, and provide other services that support the use of motor vehicles. In this report, I estimate the cost of these goods and services provided by the public sector[1]. I categorize and estimate these public-sector costs separately because governments, unlike private firms, do not charge efficient prices for their goods and services.

Table 7-1 shows direct government expenditure, in various periods from 1989 to 2003, in several of the major cost categories analyzed in this report: highways, police protection, the judicial and legal system, the correctional system (jails, prisons, probation, and parole), and fire protection. Of course, whereas all government expenditure on highways, the highway patrol, and parking is a cost of motor-vehicle use, only a portion of total government expenditure on local police, fire, jails, and so on, is a cost of motor-vehicle use. A main task in this report is to estimate the portion of the expenditures, in each general cost category (highways, police, fire, etc.), that is a long-run cost of motor-vehicle use.

Note on updated estimates. The first version of this report, published in 1998, contained estimates for the year 1991 only. In this revision I have added updated the estimates for the year 2003. The updating is fully documented throughout the report. Although some of the language in the report may still imply that analysis and results are presented for the year 1991 only, in fact results are presented for the year 2003 as well as for the year 1991.

7.1.2 Overview of the methods of the analysis

The objective in this report is to estimate the public-sector costs that would be saved in the long run if motor-vehicle use and the motor-vehicle infrastructure were reduced (-- eliminated, actually, in the reference case in which I estimate total costs). I will call this saved resource cost the “motor-vehicle-related” cost, or MVC. I estimate the MVC for the following general categories of public-sector expenditure:

- highway construction, maintenance, and administration
- municipal and institutional offstreet parking

[1]Note that I include here those public-sector costs, such as the cost of defending Persian-Gulf oil, that also can be classified as monetary externalities. See Report #1 for further discussion.

- highway law enforcement and safety
- other police protection
- fire protection
- courts
- prison, probation, and parole
- regulation and control of pollution
- research and development of motor-vehicles and motor-fuels
- other government-agency costs
- military expenditures related to the use of Persian-Gulf oil
- the Strategic Petroleum Reserve (SPR)

In each public-sector expenditure category[2] P, the motor-vehicle-related cost MVC is estimated simply as the total annualized cost, multiplied by the fraction of the total cost that would be saved were motor-vehicle use reduced (eliminated, in the reference total-cost case). I refer to this fraction as the change in the annualized cost due to change in motor-vehicle use, ΔACM. It is necessary to estimate ΔACM because, obviously, nobody keeps separate motor-vehicle accounts in the expenditure data for fire protection, police protection, and so on.

Thus:

$$MVC_P = \Delta ACM_P \cdot AC_P \qquad \textbf{[7-1]}$$

where:

MVC_P = the motor-vehicle-related cost of government infrastructure, goods, and services in expenditure category P

ΔACM_P = the fractional change in the total long-run annualized cost of the good or services in expenditure category P, due to the change in motor-vehicle use

AC_P = the total annualized cost of all government infrastructure, goods, and services in expenditure category P

subscript P = public-sector expenditure categories

The total annualized cost is equal to the annualized capital cost, including the cost of land (calculated separately in this analysis), plus annual operating, administrative, and maintenance costs. The fractional change in the total annualized cost due to the change in motor-vehicle use is estimated from two functions: one relating changes in motor-vehicle use to changes in some cost-relevant activity (such as motor-vehicle theft, or motor-vehicle fires), and the other relating changes in the cost-relevant activity to changes in total annualized cost (such as for police or fire

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[2]Except for military costs, which are not estimated with the method presented in this report.

protection). Each of these parameters (AC and ΔACM) are delineated in the following sections. For economy of exposition, the subscript P henceforth is deleted.

In general, we estimate the actual annualized cost (AC in equation 7-1) in each expenditure category through the year 2002 or 2003. However, we perform detailed estimates of the motor-vehicle-related fraction of expenditures (ΔACM in equation 7-1) for the year 1991 only, and assume that the 1991 fractions apply to all analysis years.

7.1.3 The total annualized cost of government infrastructure, goods and services in each general expenditure category

In this analysis, we use the standard annualized-cost/present-value method of investment analysis to estimate the economic cost of public-sector goods and services. In general, the total annualized cost (AC in equation 7-1) is equal to the cost of capital, annualized (or amortized) over the life of the capital at the appropriate social discount rate, plus the annual operating, administrative and maintenance costs. The annualization (or amortization) of the capital investment produces a stream of fixed annual payments whose present value is equal to the initial investment. The annualized capital costs -- not the straight capital expenditures -- are added to annual operating and maintenance costs to produce the total annualized cost[3]. One must annualize capital costs -- or, what is equivalent, estimate the present value of a stream of periodic costs -- because, fundamentally, the social value of a stream of costs or services depends on how the costs and benefits are distributed over time: usually we prefer to enjoy the benefits now and pay the costs later, rather than the other way around.

In the reference case in which I analyze the total social cost of all motor-vehicle use, the pertinent capital cost is the replacement cost of the entire capital stock, and the pertinent operating and maintenance cost is that for the entire capital stock. However, because there are no primary data sources that estimate the replacement value of the government's capital stock, and indeed no sources that estimate economic costs, as opposed to government expenditures, I must estimate the replacement cost of the capital stock and the O&M cost on the basis of the reported annual government expenditures. Formally:

$$AC = ACC + OMC \qquad \textbf{[7-2]}$$

$$ACC = \frac{NRV \cdot i}{1-(1+i)^{-t}} \qquad \textbf{[7-3]}$$

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[3] For three reasons, the simple sum of annual capital expenditures and annual O & M expenditures is not an economically useful estimate of cost. First, O & M resources are assumed to be consumed within a year, whereas capital is consumed over many years. Second, the O & M expenditures pertain to the entire existing capital stock, whereas the current annual capital expenditure represents but a portion of the total replacement value of the existing capital stock. Third, as discussed below, expenditures do not necessarily represent costs, although I assume that they do.

$$NRV = RV - RV \cdot s \cdot (1+i)^{-t}$$
$$\text{Assume } OMC = OME \qquad \textbf{[7-4]}$$

where:

AC = the annualized cost of the government infrastructure or service
ACC = the annualized capital cost: a fixed annual amount, or annuity, such that the present value of a stream of t such amounts paid at the end of each period (year) is equal to the net replacement value (NRV) of the capital at the beginning of the first period (t = 0)
OMC = the annual operating and maintenance cost
NRV = the replacement value of the capital stock, net of the present value of the salvage value of the capital, at the beginning of the first period (t = 0)
RV = the replacement value of the capital stock
s = the salvage value of the capital, expressed as a fraction of RV (I assume that s = 0, which means that NRV = RV)
i = the discount rate
t = the life of the capital: the number of periods that the capital provides services without major reinvestment
OME = the annual government expenditure for operations and maintenance for the infrastructure or service (discussed in the relevant sections below; in some cases, OME is the difference between total expenditures and annual capital expenditures, ACE, in Table 7-1)

The capital value, the life of the capital, and the assumed maintenance and repair costs must be internally consistent. That is, one must consider the life of the capital to be the period of time between the initial capital investment and the next equivalent investment given ongoing maintenance and repair of the capital stock[4].

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[4]Note that equation 7-3 annualizes the entire replacement value at t=0, which means conceptually that the entire capital stock is replaced overnight. Of course, we do not really replace the entire capital stock overnight, or all in one year; rather, we replace capital gradually, as it is worn out. But in the long run, the annualized cost of replacing the existing capital gradually is the same as the annualized cost of replacing it all at once. If capital has a life of *n* years, and every year *1/nth* of the capital stock is replaced, then the cost, calculated today, of each future *1/nth* capital replacement is an annualized cost stream equal to *1/nth* the annualized cost of replacing the entire capital stock. These yearly annualized cost streams accumulate for *n* years, at which point we will have turned over the entire capital stock and will have accumulated *n* annualized cost streams each *1/nth* the annualized cost of replacing the entire capital stock all at once.

Note, though, that if the existing capital can be liquidated such that the full value of the remaining service life of each 1/nth "piece" is recovered (i.e., such that the recoverable value is equal to the present value of the remaining original annuity payments), then the annualized liquidation value, added to annualized cost of replacing the capital as it is worn out, is the same as the annualized cost of immediately replacing the entire stock.

Thus, there are three ways to interpret our estimate of the annualized cost:

I use equation 7-3 to annualize the replacement cost of all public capital in each of the general expenditure categories listed above. To estimate the replacement value of the entire capital stock, I assume that the annual capital outlay replaces some fraction of the stock, and then scale up the annual expenditure accordingly:

$$RV = \frac{ACE}{ARF} \qquad \textbf{[7-5]}$$

where:

ACE = annual capital expenditures (discussed below, and in the relevant sections; year-specific actual values used, e.g. from Table 7-1)
ARF = annual capital replacement factor: the fraction of the total capital stock that is replaced each year by the annual capital expenditure ACE (Table 7-2; values assumed to be the same for all years)

The best source of expenditure data for highways, including the highway patrol, is the widely cited *Highway Statistics* annual report, which presents the results of expenditure surveys sent to State transportation departments (DOTs). The best source of data on expenditure for police protection, fire protection, courts, and corrections, is the original survey data published by the Bureau of the Census, in its annual *Government Finances* report. The Census reports direct or final expenditures by function, rather than by agency, which suits my purposes well. The Census data are consistent with similar data in other sources, and according to the Census generally are more inclusive than any other source. In the relevant subsections, below, I present the Census' description of the relevant expenditure areas (Bureau of the Census, *Classification Manual*, 1992), and the particular functions within the general area that are attributable to motor-vehicle use. The best source of data on expenditures for pollution control, abatement, and regulation is the Bureau of Economic Analysis (BEA), which combines survey data from the Bureau of the Census with its own original estimates. Various data sources are used for the other expenditure categories.

Tables 7-1 and 7-3 present data series used to estimate ACE and OME for the expenditure categories "highways," "highway law enforcement and safety," "other police protection," "fire protection," "courts," and "prison, probation, and parole," through the year 2002 or 2003. The actual estimates of ACE and OME for these and other categories, for the year 1991, are summarized in Table 7-2.

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i) as the annualized cost, beginning today, of replacing the entire capital stock immediately;

ii) as the annualized cost in the long run (after n years, where n is the life of the capital) of continuing to replace capital as it is normally worn out; or

iii) as the annualized cost, beginning today, of continuing to replace capital as it is normally worn out, *and* of failing to fully liquidate the capital in place.

Land costs. Generally, one distinguishes land from other capital, because land yields services in perpetuity. Land is not "consumed;" rather, at the end of a project it is as available for other uses as it was at the beginning of the project. Hence, for land, the life t is infinite, and the annualization formula simplifies to:

$$ACC_{Land} = TV_{Land} \cdot i \qquad \textbf{[7-6]}$$

where:

TV_{Land} = the value of the total land stock, analogous to the replacement value of the total capital stock.

The FHWA, Census, and BEA estimates of capital expenditures include expenditures for land. Because, as just shown, the cost of land is annualized differently from the cost of other capital, I must separate reported expenditures on land from reported total expenditures on capital. Table 7-2 shows my estimates of reported expenditures on land as a fraction of reported total capital expenditures. (I assume that these estimates apply to all years, not just to 1991.) I deduct reported land expenditures from reported total capital expenditures, scale the remainder to the level of the entire capital stock, and then annualize the resultant total value using equation 7-3.

I use equation 7-6 to annualize the total value of all land used by public capital related to motor-vehicle use. I estimate the total value of land by scaling the annual vale of land used for new capital projects to the level of the entire capital stock. The annual value of land used for new capital projects is estimated as a fraction of annual total capital expenditures. Note, though, that the annual value of land used for new capital projects will exceed reported expenditures for land in new capital projects if governments do not report the value of land for new capital projects on land that they already own, or if in general they pay less than market value[5]. For example, if a state highway agency rebuilds a road on land that it acquired well before the start of the rebuilding, it will report the cost of the right-of-way for the rebuilding as zero. As discussed in section 7.2.7, there is some evidence that this is the case. In the extreme, if all new capital projects today just replaced worn-out capital on government land, total

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[5]If the government pays less than full market prices for land, then reported expenditures on land understate the true opportunity cost of the land. (In a properly functioning market for land, the price of land reflects the true opportunity cost. The price is equal to the capitalized value of the annual rent, which in turn is equal to the marginal product of land as an input to production multiplied by the value (or price) of the marginal product.) However, Beshers (1994) claims that there is not much evidence that the government buys land for highways at below market prices.

There may be specific public policies, especially taxation policies, that distort the market for land, or distort the value of undeveloped land relative to the value of developed land. For example, Lee (1992) notes that "property tax practices that tax actual improvements rather than the potential for intensive use (i.e., a land tax) suppress development below its optimal intensity, thus favoring parking as a land use" (p. 10).

reported expenditures for land would be zero. But the cost of the land of course would not be zero, because alternative uses still would be foregone. The cost in fact would be precisely what the government would pay for the land, in a free market, were it not already the owner.

Overall expression for the total annualized cost. Combining equations 7-2 to 7-6, and accounting for the difference between reported land cost and true land cost, I estimate the total annualized cost as follows:

$$AC = \frac{ACE}{ARF} \cdot (1 - RLC) \cdot \frac{i}{1-(1+i)^{-t}} + \frac{ACE}{ARF} \cdot (TLC) \cdot i + OME \qquad \textbf{[7-7]}$$

where:

AC, ACE, ARF, i, t, and OME are as defined above
RLC = land costs included in ACE, as a fraction of ACE (Table 7-2)
TLC = true total land costs for new capital projects (included plus not-included costs; expressed as a fraction of ACE) (Table 7-2)

Table 7-2 shows the values of the parameters i (for all years), t (for all years), ACE (for 1991), OME (for 1991), ARF (for all years), RLC (for all years), TLC (for all years), and ACC (for 1991).

7.1.4 The fractional change in total annualized cost due to changes in motor-vehicle use (ΔACM), in each expenditure category

For each expenditure category listed in section 7.1.2, we need to know the fraction of the total annualized cost that is a long-run cost of motor-vehicle use. It is immediately clear that for highways, parking, and the highway patrol, the fraction ΔACM is equal or very close to 1.00 (when the change in motor-vehicle use is 100%). However, for all of the other expenditure categories, ΔACM must be estimated.

Figure 7-1 illustrates the estimation of the motor-vehicle share of government cost for infrastructure, goods and services for all expenditure categories other than highways, highway patrol, and parking. I presume that, in general, the total annualized cost in these categories is a nonlinear function of some cost-relevant activity, such as reported crimes, arrests, fires, prisoner-months of incarceration, minutes of court time, pollution, and so on. Given this general relationship, one can estimate the long-run motor-vehicle related cost by estimating the motor-vehicle related fraction of the cost-relevant activity (e.g., the motor-vehicle share of pollution).

The general annualized cost function is illustrated in Figure 7-1, where cost and activity are expressed as a fraction of total cost and total activity in the reference year, 1991. The functional form is simply:

$$ACF = AF^{k}$$

$$ACF \equiv \frac{AC}{AC_{91}} \qquad \textbf{[7-8]}$$

$$AF \equiv \frac{A}{A_{91}}$$

where:

ACF = the total annualized cost of government infrastructure, goods, and service, in the long-run, expressed as a fraction of the total annualized cost of the government service or infrastructure provided or in place in 1991
AF = the activity related to the cost of the infrastructure or service, expressed as a fraction of the total activity in 1991 (crimes, arrests, fires, prisoners, and so on)
k = the shape exponent (discussed below, and in the individual cost sections)
AC = the total annualized cost of government infrastructure and service (equation 7-7)
AC_{91} = the total annualized cost of the government service or infrastructure provided or in place in 1991
A = the cost-relevant activity (crimes, arrests, fires, etc.)
A_{91} = the actual total activity level in 1991

In 1991, the reference year of this analysis, there was for each government expenditure category some total cost-relevant activity (A_{91}; in Figure 7-1, AF_{91}), and an associated total capital stock and O&M expenditure. The amortized replacement cost of the entire 1991 capital stock, plus the 1991 O&M cost, equals the annualized total cost (AC_{91}; in Figure 7-1, ACF_{91}). If there had been less motor-vehicle use in 1991 then there actually was, then there would have been less of the relevant activity (crimes, fires, pollution, etc.), and consequently less associated O&M and, in the long run, capital. In general, as illustrated in Figure 7-1, the "initial" activity fraction before the change in motor-vehicle use is $AF_{0,}$ and the activity fraction after the change in motor-vehicle use is $AF_{\Delta AM}$. At the initial activity fraction AF_0, the total long-run annualized cost fraction is ACF_0, and at the post-change activity fraction $AF_{\Delta AM}$, the total long-run annualized cost fraction $ACF_{\Delta ACM}$. The difference between ACF_0 and $ACF_{\Delta ACM}$ is the figure of interest in this analysis: the change in the annualized cost fraction due to a change in motor-vehicle use (ΔACM):

$$\Delta ACM = ACF_0 - ACF_{\Delta ACM} \qquad \textbf{[7-9]}$$

Substituting for ACF, from equation 7-8:

$$\Delta ACM = AF_0{}^k - AF_{\Delta AM}{}^k \quad \textbf{[7-10]}$$

Finally, the activity fraction after the change in motor-vehicle use, $AF_{\Delta AM}$, is estimated as the difference between the initial activity fraction, AF_0, and the fractional change in total activity due to the change in motor-vehicle use, ΔAM. Hence:

$$\Delta ACM = AF_0{}^k - (AF_0 - \Delta AM)^k \quad \textbf{[7-11]}$$

and:

$$MVC = \left(AF_0{}^k - (AF_0 - \Delta AM)^k\right) \cdot AC \quad \textbf{[7-12]}$$

where:

$ACF_{\Delta ACM}$ = the total annualized cost of government infrastructure, goods, and service, in the long-run, after a change Δ in cost due to a change in motor-vehicle use; expressed as a fraction of the total annualized cost of the government service or infrastructure provided or in place in 1991

$AF_{\Delta AM}$ = the activity related to the cost of the infrastructure or service, after a change Δ in total activity due to a change in motor-vehicle use; expressed as a fraction of the total activity in 1991 (crimes, arrests, fires, prisoners, and so on)

AF_0 = the initial activity, before the change in motor-vehicle use; expressed as a fraction of total activity in 1991 (I will assume 1.0, for the estimates in this analysis)

ΔAM = the change in total activity due to the change in motor-vehicle use; expressed as a fraction of total activity in 1991

all other terms are defined above

We thus have two major parameters to estimate in equation 7-11:

• the shape of the total cost function (the exponent k)
• the fractional change in total activity due to a change in motor-vehicle use (ΔAM)

Both of these are discussed further below.

In the reference analysis of the total cost of motor-vehicle use, the change Δ considered is, of course, all motor-vehicle use. However, I emphasize that this is just a reference case, and that with the equations presented here, the analysis can be conducted for any change in motor-vehicle use.

The shape of the long-run total cost function. The simple function AF^k can represent any monotonically increasing cost versus activity level. As the exponent k approaches zero, the cost function approaches a step function, with the first step equal to 1.0 (i.e., at almost any activity fraction, cost is nearly 100% of cost in 1991). As the exponent k approaches infinity, cost approaches zero at all activity levels. When k = 1.0, cost is proportional to activity. In terms of the marginal cost, $-cost/unit-activity, which is the first derivative of the total cost function:

k < 1.0 $-cost/unit-activity decreases with increasing activity
k = 1.0 $-cost/unit-activity is constant over all activity
k > 1.0 $-cost/unit-activity increases with increasing activity

Why, in the long run, is k not necessarily equal to 1.0? That is, why isn't cost proportional to activity, and the $-cost/unit-activity constant? There are several reasons.

i) Scarcity (tends to make k > 1.0). First, in a world of scarce resources, the cost per unit of capital and the cost per labor unit increase with increasing use of capital and labor. This factor alone implies that k > 1.0. However, there are at least two possibly countervailing factors, which might tend to make k < 1.0: capital, managerial, and administrative costs don't necessarily scale with size, output, or labor force; and physical capacity might be determined mainly by specific kinds of activities (e.g., infrequent but large and serious fires) rather than by the total amount of activity (e.g., all fires). These are discussed next.

ii) Scale economies (tend to make k < 1.0). Most capital costs don't scale linearly with size or output or activity. A building for 50 police officers is not twice as expensive as a building for 25 police officers, even if the larger building has exactly twice the floor space, because the larger building will not have twice as much material, and will not require twice the man-hours to build. For example, a 60'x60' building has 100% more square footage but only 70% more wall perimeter than a 42'x42' building. Both buildings might have only one bathroom. The heating and air-conditioning system in the larger building might have to move twice as much air, but it will not have to do twice the total work (because the surface/volume ratio of the larger building will less), and even if it did, it still will not cost twice as much as the system in the smaller building.

Of course, if capital is added in discrete units, such that 50 officers have two identical 42'x42' buildings instead of one 60'x60' building, then the cost of capital does scale with quantity.

For much the same reasons, the number of administrators and managers is not necessarily proportional to the output or activity of the government agency. A prison probably will have a warden whether it has 100 prisoners or 200, and a fire department will have fire chief whether it has 10 firefighters or 20. The costs of Federal administrative and statistical agencies probably aren't terribly sensitive to the number of prisoners, fire departments, and so on.

Yet there are countervailing possibilities here, too. If the fire department is small enough, the fire chief might also be serving as the police chief or mayor, too. At some point, independent statistics agencies might merge with others and perform a wider range of tasks.

iii) Capacity requirements (tends to make k < 1.0). If the capacity of a government service, such as fire-fighting, is based mainly on a worst-case scenario (such as a block fire in a high-density residential neighborhood), and not on the total number of events, or on the frequency of certain types of events, then a reduction in the number of events (fires), or even a [moderate] decrease in the frequency of worst-case events, will not reduce the desired capacity.

If, however, the capacity is based on the frequency as well as the magnitude of certain events, then a reduction in frequency may reduce capacity. For example, once the frequency of activity (crime, fires) in a certain area drops below a threshold, the relevant government capacity locally might be eliminated, and the functions (policing, fire fighting) left to a larger nearby department.

v) My assumptions. Generally, I assume that the capital and administrative "scaling" effect (number *ii* above) roughly cancels the scarcity effect (number *i* above), so that the value of the shape exponent is determined mainly by the capacity-factor effect (number *iii*). This is discussed further in the relevant cost sections below.

The change in activity due to the change in motor-vehicle use. The parameter ΔAM in equation 7-11 is the change in activity (as a fraction of total activity in1991) due to a change in motor-vehicle use. I assume that the relationship between activity and motor-vehicle use is of the same form as the relationship between cost and activity: activity, expressed as a fraction of total motor-vehicle-related activity, is related to changes in motor-vehicle use, expressed as a fraction of total motor-vehicle use, by a simple exponential function, illustrated in Figure 7-2:

$$AMF = MVUF^{r} \qquad \textbf{[7-13a]}$$

where:

AMF = the activity related to a particular level of motor-vehicle use, expressed as a fraction of total motor-vehicle related activity (activities are motor-vehicle related crimes, fires, etc.)

MVUF = motor-vehicle use, expressed as a fraction of total motor-vehicle use (motor-vehicle use can be expressed, for example, in vehicle-miles of travel)

r = the shape exponent, analogous to k in equation 7-8

To estimate the change in activity (as a fraction of total motor-vehicle-related activity) associated with a change in motor-vehicle use, we proceed as we did with equations 7-9 to 7-11, and end up with:

$$\Delta AM^{*} = MVUF_{0}^{\,r} - \left(MVUF_{0} - \Delta MVU\right)^{r} \qquad \textbf{[7-13b]}$$

where:

ΔAM* = the change in activity (as a fraction of total motor-vehicle-related activity) associated with a change in motor-vehicle use
$MVUF_O$ = the initial level of motor-vehicle use, expressed as a fraction of total motor-vehicle use in 1991
ΔMV = the change in motor-vehicle use, expressed as a fraction of total motor-vehicle use in 1991

I do not see any basis for having the initial level of motor-vehicle use be anything other than the total level in the reference year, 1991. Hence, I will take $MVUF_O$ to be equal to 1.0 (i.e., 100% of motor-vehicle use in 1991). Thus:

$$\Delta AM^* = 1 - (1 - \Delta MVU)^r \quad \textbf{[7-13c]}$$

This is illustrated in Figure 7-2.

Note that ΔAM* is with respect to total *motor-vehicle-related* activity (e.g., all crimes nominally related to motor-vehicle use), whereas ΔAM (without the asterisk) is with to all of the relevant activity (e.g., all crimes). Equation 7-11 uses the change with respect to all crimes, ΔAM. The relationship between ΔAM* and ΔAM of course is straightforward:

$$\Delta AM = \Delta AM^* \cdot \frac{A_{TMV}}{A_T} \quad \textbf{[7-13d]}$$

where:

A_{TMV} = the total activity, in government expenditure category P, associated with all motor-vehicle use (e.g., the number of fires related to motor-vehicle use: motor-vehicle fires, gas-station fires, car-dealership fires, and so on)
A_T = the total activity in expenditure category P (e.g., the total number of fires)

Thus, combining 7-13c and 7-13d, we get the final expression for ΔAM:

$$\Delta AM = \left(1 - (1 - \Delta MVU)^r\right) \cdot \frac{A_{TMV}}{A_T} \quad \textbf{[7-13e]}$$

where all of the terms are defined above.

Substituting equation 7-13e into equation 7-11 yields the final equation for ΔACM:

$$\Delta ACM = AF_0^{\ k} - \left(AF_0 - \left(1 - \left(1 - \Delta MVU\right)^r\right) \cdot \frac{A_{TMV}}{A_T} \right)^k \qquad \textbf{[7-13f]}$$

Table 7-2 shows the value of all the parameters in equation 7-13f. The values for the two key parameters, the exponent k and the ratio of motor-vehicle activity to total activity, $\frac{A_{TMV}}{A_T}$, are discussed and estimated in the sections pertaining to the individual expenditure areas, below. *Note that I perform detailed analyses of the activity fractions* $\frac{A_{TMV}}{A_T}$ *for the year 1991, and then assume that the estimated year-1991 fractions apply to all analysis years.*

Two things to note. First, if ΔMVU = 100%, then $\Delta AM' = \frac{A_{TMV}}{A_T}$. Second, in the special case of highways, highway patrol, and parking, the cost-relevant activity is motor-vehicle use itself, so that ΔAM* = ΔMVU, and hence:

$$\Delta ACM_{HWY,PK} = AF_0^{\ k} - \left(AF_0 - \Delta MVU \cdot \frac{A_{TMV}}{A_T} \right)^k \qquad \textbf{[7-13g]}$$

<u>The shape of the activity/motor-vehicle use function.</u> This function is analogous to the cost/activity function (equation 7-8), and the shape parameter here is analogous to the shape parameter k in equation 7-8. Without doing a formal analysis of the relationship between motor-vehicle use and the cost relevant activities, I simply assume that in every case, activity is proportional to motor-vehicle use, which means that r = 1.0 This assumption of course begs for a real analysis.

<u>The activity measures.</u> So what are the activity measures A in equation 7-13? In each expenditure category (police, fire, etc.), I have picked activity measures that relate to total costs on the one hand (because costs are estimated as a function of activity), and to motor-vehicle use on the other. Thus, for example, I apportion the cost of the judicial system on the basis of time spent on hearing different types of cases (murder, robbery, and so on), and the cost of the correctional system on the basis of prisoner-months of incarceration by type of offense. The choice of the activity measure, and the estimate of the motor-vehicle-related activity fraction, are developed in the sections below pertaining to each government expenditure category.

In the case of activity measures that are related to crime (e.g., arrests by type of offense), I first, estimate what I call a "nominal" $\frac{A_{TMV}}{A_T}$, and then adjust the nominal $\frac{A_{TMV}}{A_T}$ to account for "substitution" effects. The nominal $\frac{A_{TMV}}{A_T}$ includes all crimes that, on the face of it (i.e., nominally) might be "related" to motor-vehicle use: for example, it includes all robberies in parking lots. However, one cannot assume that if there a change in motor-vehicle use, then total crime would decline by the total amount of crimes nominally related to the change in motor-vehicle use, because some of those now committing crimes nominally related to motor-vehicle use would find other criminal activities. I adjust for such "substitution" effects in regards to all resources devoted in any way to criminal activity.

Inevitably, many of my adjustments or measures are ad-hoc or mere guesses. Nevertheless, in most cases the range of results appears to be reasonable.

7.1.5 The final equation for the motor-vehicle-related cost

Substituting equations 7-7 and 7-13f into equation 7-1 yields the following overall equation for determining the motor-vehicle related cost MVC:

$$MVC = \left(AF_0^{\ k} - \left(AF_0 - \left(1 - (1 - \Delta MVU)^r\right) \cdot \frac{A_{TMV}}{A_T} \right)^k \right) \cdot \left(\frac{ACE}{ARF} \cdot \left((1 - RLC) \cdot \frac{i}{1 - (1+i)^{-t}} + \cdot (TLC) \cdot i \right) + OME \right) \qquad \textbf{[7-14a]}$$

where all of the terms are defined above. In the special case of highways, highway law enforcement and safety, and parking:

$$MVC_{HWY,PK} = \left(AF_0^{\ k} - \left(AF_0 - \Delta MVU \cdot \frac{A_{TMV}}{A_T} \right)^k \right) \cdot \left(\frac{ACE}{ARF} \cdot \left((1 - RLC) \cdot \frac{i}{1 - (1+i)^{-t}} + \cdot (TLC) \cdot i \right) + OME \right) \qquad \textbf{[7-14b]}$$

Furthermore, for a 100% change in motor-vehicle use, equation 7-14b reduces to equation 7-7.

Note that in all of the estimates in this report, I assume that the initial activity is the total activity in 1991, so that AF_O = 1.0 (see the discussion in section 7.1.6). Also, I note again that I assume that changes in motor-vehicle-related activity are linearly related to changes in motor-vehicle use, so that the exponent r = 1.0 in all cases. (Note too that I perform detailed analyses of the activity fractions $\frac{A_{TMV}}{A_T}$ for the year 1991, and then assume that the estimated year-1991 fractions apply to all analysis years.) Finally, all data, tables, and calculations, except the results shown in part of Table 7-23, pertain to a 100% change in motor-vehicle use (ΔMVU = 1.0).

7.1.6 Other issues

Short-run versus long-run costs. In many cases, a sizable fraction of the total long-run cost is fixed in the short run, and hence not saved immediately as a result of a reduction in motor-vehicle use. For example, a change in motor-vehicle use today -- even a very big change -- will have a relatively small immediate effect on total fire-protection costs, because much of the total cost of fire protection is a capacity cost, which is foregone, if at all, only in the long run. Figure 7-1 shows the short-run cost curve, lying above the long-run cost curve by the amount of the short-run fixed cost B. In this report I estimate only the long-run cost.

Public versus private resource allocation. Decisions regarding publicly owned and managed resources are made, naturally, by public officials, rather than by private owners of capital. Whereas private owners of capital presumably manage their resources economically efficiently (i.e., to maximize profit given input costs and product prices), public managers of public resources generally do not, at least not explicitly. Public managers might consider criteria other than economic efficiency in their investment decisions. Consider the hypothetical case in which a large reduction in motor-vehicle use noticeably reduces the need (i.e., contracts the “demand”) for police services. Economic efficiency might dictate a reduction in resources devoted to police protection, and if police departments were run as businesses, we might expect then in the long run a reduction in police-protection costs. But police departments are not managed as businesses, and some public officials who allocate resources to police protection might think it politically unwise to spend less on police protection.

Nevertheless, I have assumed that public officials *do* allocate resources on the basis of the “demand” for the relevant services, where the demand is represented by the activity measures A of equation 7-13.

Where on the margin? For any value of the shape exponent k other than 1.0, it matters where on the total cost curve you “start” when activity levels change due to a change in motor-vehicle use. (In other words, the value of AF_0 in equation 7-14 matters.) In the case of decreasing \$/activity-unit with increasing activity, as shown in Figure 7-1, a reduction in activity from 1.00 to 0.90 will save less cost than will a reduction from 0.10 to 0.0. That is, in this case, the cost of motor-vehicle use will be greater if motor-vehicle use is the *last* cost-occasioning use of government resources that one eliminates.

However, in this analysis, I always assume that only motor-vehicle related costs are eliminated; i.e., that the initial activity level is total activity in 1991, so that the AF_0 and $AF_0^K = 1.0$.

Issues not addressed: producer surplus, transfers, deadweight loss, and general equilibrium price effects. For at least three reasons, it is likely that FHWA, BEA, and Census expenditure data do not represent purely economic cost. First, even if competitive bidding forces each contractor to offer no more than his minimum willingness to supply, the amounts that the highway contractors, building contractors, and others pay for materials and services (and which they incorporate into their bids) include producer surplus. In principle, this producer surplus, which is revenue in excess of economic cost (i.e., the area between the price line and the supply curve), should be excluded from an estimate of economic cost. Second, in the case of public expenditures, not only does one have to worry about producer surplus, but, as Lee (1992) notes, "it is possible to argue that kickbacks from corrupt contractors and [a portion of] politically inflated labor rates are transfers, not costs" (p. 19; bracketed comments mine). Third, to the extent that government expenditures are financed from incremental general tax revenues, the economy suffers deadweight losses of consumer and surplus due to the contraction of consumption and production caused by price distortion by the incremental taxes. However, if the tax revenues are not incremental -- that is, if there is a fixed amount of tax revenue available regardless of highway expenditures -- there is no incremental deadweight loss associated with highway expenditures. Also, to the extent that government expenditures are financed from efficient user prices rather than from taxes, there is no price distortion and hence no deadweight loss.

Finally, changes in the provision of public motor-vehicle infrastructure and services can lead to changes in the price and consumption of major commodities, such as steel, which in turn can result in real costs or benefits to the U. S. Suppose, for example, that new highway construction significantly expands demand for steel. This expansion will increase the price of steel, and thereby reduce consumption of steel in other sectors and transfer wealth from consumers to producers. In a global cost-benefit analysis, this wealth transfer is not be a real cost or benefit; however, if we restrict the analysis to the welfare of the U. S., then any transfer from U. S. consumers to foreign steel producers is a real cost to the U. S.

I do not formally address any of these issues in this analysis.

There are other issues of concepts, methods, and data, discussed in the pertinent sections below.

7.2 ANNUALIZED COST OF PUBLIC HIGHWAYS, EXCLUDING PRIVATE INVESTMENT IN ROADS, BUT INCLUDING ON STREET PARKING: HIGHWAY CONSTRUCTION, MAINTENANCE, AND ADMINISTRATION

7.2.1 Overview

The objective in this section is to estimate the annualized cost of public highways, excluding *private* investment in roads, which is estimated in Report #6. The annualized cost is estimated with equation 7-14b. Table 7-2 shows values for some of the parameters in equation 7-14b. The major data sources used to estimate annual capital and O&M expenditures, and adjustments thereto, are discussed in the following section.

The FHWA collects data on total government and private-sector expenditures for highways, including expenditures on capital, operations and maintenance, highway police and safety, administration and research and miscellaneous, and debt retirement and interest (FWHA, *Highway Statistics*, various years). Unquestionably, the FHWA's is the most comprehensive, careful, and reliable estimate of expenditures for highways (excepting its estimate of private investment in highways). I have reviewed the FHWA's classification and estimates of expenditures in considerable detail, looking for inappropriate inclusions or exclusions. The notes to Table 7-3 give a partial listing of the expenditure items included in the FHWA's estimates (see FHWA, *Highway Statistics*, various years; and FHWA, *A Guide to Reporting Highway Statistics*, 1990; Hu et al., 1991). My review, and my lengthy correspondence with the FHWA's Office of Highway Information and Management, indicate several differences between the social cost that I wish to estimate, and the expenditures that FHWA reports. The most important difference is between annual capital expenditures and the annualized replacement cost of all capital, as discussed above. Other differences are discussed below. Tables 7-3 and 7-4 summarize the FHWA expenditure data, and my exclusions and additions to the FHWA data in my estimate of the social cost.

Note that the FHWA excludes some government agency expenditures that are related to motor-vehicle use but that the FHWA does not consider to be related to highway use per se: air-quality agencies, energy agencies, environmental agencies, and so on. I estimate the motor-vehicle-related cost of these agencies in sections 7.8 and 7.9.

7.2.2 Bond retirement and interest.

The FHWA reports "debt retirement and interest," which includes interest and redemption costs, costs of preparing and issuing bonds, fiduciary fees, printing fees, and legal opinions. However, the interest and redemption cost, which presumably is the lion's share of the category, is not a real resource cost *in addition* to the annualized capital cost: the bond proceeds themselves (the redemption cost) eventually are spent on capital, and the interest on the bonds is part of the interest charge embedded in the annualized capital cost. Hence, my estimate of the annualized capital cost necessarily includes any costs of bonds and bond debt used to finance capital improvement.

However, the other expenditures in the category -- the costs of preparing and issuing bonds, fiduciary fees, printing fees, and legal opinions -- are real resource costs in addition to capital expenditures. I assume that these real additional costs are 10% of the costs in the category "debt retirement and interest," and count this additional 10% in the grand total of Table 7-3.

7.2.3 Collection expenses

It costs money to collect and administer funds related to the use of motor vehicles. For example, public agencies incur costs collecting motor-fuel taxes and motor-vehicle registration fees, or in administering general funds applied to highway- or motor-vehicle-related purposes. Clearly, all costs associated with collecting and administering funds related to motor-vehicle use are real costs of motor-vehicle use: if there were no motor-vehicle use, there would be no motor-vehicle-related taxes and fees to collect, and hence no collection and administration costs. This applies to the collection of general revenues used for motor-vehicle-related purposes as well as to the collection of motor-vehicle-user imposts.

In Table DF of *Highway Statistics*, the FHWA shows the amount of money spent by states for "collection and administration of highway-use taxation". However, the FWHA does *not* include the collection-cost amount in its summary of total expenditures on highways (see notes to Tables HF-1 and HF-10), and furthermore, it *deducts* the amount from gross receipts from imposts on motor-vehicle users. As suggested above, I will not follow the FHWA's convention, because for my purposes administration and collection of receipts is as a real a motor-vehicle related cost as is concrete for highways, and user fees used for administration and collection are still user fees. Consequently, I have counted the amount from Table DF as both an expenditure for motor-vehicle use (Table 7-4), and a payment by motor-vehicle users (Report #17 of this social cost series). (In the summary Table 7-23, I show these collection expenses as a separate line item.)

However, FHWA's Table DF shows only states' costs of collecting user fees, even though other levels of government, and other state agencies, also incur costs to collect and administer funds related to motor-vehicle use. As far as I can tell, the FWHA does not account anywhere for the collection costs of other levels of government or other state agencies. Consequently, I have estimated these additional collection costs and added them to FHWA-reported states' collection costs. I have assumed that collection costs are proportional to total receipts for highways. Thus, I scale reported state collection costs (Table DF in *Highway Statistics*; $2.14 billion in 1991) by the ratio of all receipts for highways to receipts from state imposts on highway users ("Receipts available for distribution," Table DF, *Highway Statistics*)[6].

7.2.4 Leaking underground storage tanks.

Since January 1, 1987, a small portion of the federal excise tax, $0.001/gallon, has been dedicated to the leaking-underground- storage-tank trust fund. The FHWA does *not* count the total amount of the tax as either an expenditure on or receipt for highways. Although it probably is reasonable to exclude this from a cost accounting for highways, which is what FHWA's is, it is not reasonable to exclude it from a cost accounting for motor-vehicle use, because the majority of leaking underground storage tanks contain motor-fuel. Consequently, I have multiplied the $0.001/gallon tax by net gallons of motor-fuel taxed (from Table MF-2 of *Highway Statistics*) and have counted the entire amount as an expense of motor-vehicle use. Note, though, that I also include the $0.001/gallon tax in my estimate of payments for motor-vehicle use by motor-vehicle users.

Collection of the tax was suspended from September 1 1990 to December 1 1990. The tax expired on January 1, 1996, but was reinstated on October 1, 1997, and will expire again on March 31, 2005 (FHWA, 1997). Given this, my treatment of the tax (as representing a cost of motor-vehicle use) is as follows:

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[6] See Report #17 for an explanation of the treatment of collection expenses on the "user payments" side of the ledger.

Period	LUST-fund tax ($/gal)	% of annual fuel volume subject to tax
before 1987	0.000	0%
1987 through 1989	0.001	100%
1990	0.001	assume 75% (9 months)
1991 through 1995	0.001	100%
1996	0.000	0%
1997	0.001	assume 25% (3 months)
1998 through 2004	0.001	100%
2005	0.001	assume 25% (3 months)
after 2005	0.000	0%

7.2.5 Under maintenance: deterioration of infrastructure.

The FHWA reports current expenditures on capital, maintenance, and repair. However, it has been widely believed that these current expenditures have not been sufficient to maintain the conditions of the roads -- i.e., that the existing infrastructure has been deteriorating (Memmot et al. 1993; *The 1991 Status of the Nation's Highways and Bridges* , FHWA, 1991). Although any net deterioration is not an additional capital or O & M cost today, because the depreciation of the current capital stock already is accounted for in the annualization of the capital cost of the infrastructure, it does imply a real resource cost in the future. As Lee (1992, p. 25) notes, if the system is deteriorating, then in the future "either expenditures must increase or the extent of the network must be reduced" -- or, I would add, a lower level of service must be accepted. If one believes that in order to reverse the deterioration, maintenance and repair expenditures will increase, in real terms, then current FHWA-reported maintenance and repair expenditures underestimate future real expenditures. If one believes that a lower level of service will be accepted, or the extent of the network reduced, then users will experience higher costs of travel time, comfort, vehicle operation, accidents, and so on, and also forego some trips. In this latter case, current estimates of the costs of travel time, comfort, etc., underestimate future real costs, all else equal.

Analysts have estimated how much maintenance and repair expenditures must increase to arrest deterioration. A relatively old study by the Congressional Budget Office (cited in Memmot et al., 1993) estimated that the difference between then-current spending and the amount that would be necessary to maintain current conditions would be about $3 billion per year. Of course, the optimal investment strategy -- the one that maximizes net benefits -- might be to do more (or perhaps even less) than just maintain current conditions. For example, Memmot et al. (1993) estimated that it would be worthwhile to spend more than $10/billion per year extra from 1985 to 2000 to improve (not merely maintain) the performance of the highway system.

However, our time series of highway expenditures (Table 7-3) includes data through 2003, and it is not clear to what extent the most recent O&M expenditures are insufficient to maintain current highway conditions. Moreover, whether or not we should count under-maintenance as a cost depends on the purpose of our study. To the extent that we wish only to report historical costs, then undermaintenance, which is manifest as a resource cost in the future, should be ignored. However, if we wish to predict future costs, then we ought to take some account of present undermaintenance. I am reporting historical costs, and hence will ignore any future undermaintenance costs, but I remind readers that in the future maintenance and repair costs may increase by several billion dollars per year more than recent trends would imply, in order to prevent further deterioration of the infrastructure.

7.2.6 Removing embedded estimates of private investment in the highways.

The FHWA asks state and local reporting agencies to include private investment in highways in the expenditure accounts sent to FHWA. FHWA's *A Guide to Reporting Highway Statistics* (1990, p. 8-7) states: "Private -sector participation in financing highway projects takes the form of cash contributions and other donations, transfers of real property, construction of facilities, and services such as engineering. When the value of donated land, facilities, or services is reported in item B.14 [of form FHWA-531, State Highway Income], a like amount should be added to items A.1 [capital outlay on state system], A.7 [county and township roads], A.8 [local and municipal roads], and A.11a [other roads not in state system] [of form FHWA-532, State Highway Expenditures], as appropriate, in order to account for the total investment in public highways" (brackets are mine). The FHWA includes the estimated private contribution in its reported "capital outlay," which is shown in column *a* of Table 7-3 here.

In our accounting, private contributions to highway financing are properly classified as a "motor-vehicle good or service bundled in the private sector" (in Report #6) rather than as a public-sector expenditure for the highways. This is because the resources are provided by the private sector, not the public sector, and because the cost of the resource is recovered ultimately in the price of bundled commodities (e.g., the cost of local roads is recovered in the price of houses), not from user tax and fee payments to government. Therefore, we must estimate and deduct the amount of the private contribution embedded in the FHWA's estimates of capital outlays, in order to be left with an estimate of public-sector capital outlays for the highway.

FHWA does not report the amount of the private investment embedded in its estimates of capital outlays. However, Hu et al. (1991) have made an estimate of the total amount of private investment in highways, including amounts that are reported to FHWA and included in FHWA capital-outlay estimates. Hu et al. (1991) estimate that the 1989 capital-outlay figure reported by FHWA includes $1.6 billion dollars of private investment in collectors and arterials, which they call "off-site" roads, as distinguished from local roads or "on-site" roads that are an immediate part of a development[7]. I

[7] Hu et al. (1991) also estimate that there were *additional* private expenditures, not reported to FHWA, of $3.2 billion on off-site collectors and arterials, and $6.4 to $22 billion on local "on-site" roads (See also *The 1991 Status of the Nation's Highways and Bridges*, FHWA, 1991). We include all these in our estimates of total private investment in roads in Report #6.

assume therefore that in 1989 the capital outlay figure in column *a* of Table 7-3 includes \$1.6 billion in private investment. Starting with this figure, I use my judgment to estimate the historical series shown in Table 7-4. (Note that I show the deduction of embedded private costs as a separate line item in summary Table 7-23.)

7.2.7 Land costs not included in State DOT estimates

As mentioned above, it is likely that State DOTs do not report as a capital expenditure in year Y the value of land that was used for a new road project in year Y but which the government owned long before Y.

FHWA data on the cost of right-of-way hint that this might be occurring. The cost of acquiring right-of-way for state highways, as a percentage of the total capital outlay for highways by states, has declined from roughly 15% in the 1950s and 1960s to about 10% in the 1970s and even less than 10% in the 1980s and 1990s (except 1992) (FHWA, *Highway Statistics, Summary to 1995*, 1997; I do not incorporate expenditures by local governments because according to FHWA, local governments might mis-report the cost of right-of-way under general construction.) This decline suggests something like the following scenario: in the 1950s the government bought land and built a road, and reported the cost of acquiring the right-of-way along with the cost of the actual construction; in the 1990s, the government rebuilt the road on the land that it already owned, and reported only the cost of the new construction.

Now, given that our estimate of annualized capital cost (Table 7-4) is based on the assumed true land cost, and not on the reported land expenditure (because equation 7-7 uses the true land cost), we do not actually need to make a separate estimate of the land costs not included in the State DOT estimates. Nevertheless, it is interesting to see the likely magnitude of the costs not included, so in Table 7-4, I show how much more would be reported each year if the FHWA reported as a capital expenditure the omitted land cost:

$$LNI = ACE_{HWY} \cdot (TLC - RLC) \qquad \textbf{[7-15]}$$

where:

LNI = annual land cost not included in annual capital expenditure reported by FHWA (\$)

ACE_{HWY} = annual capital expenditures for highways, reported by FHWA (\$; Table 7-3)

RLC = land costs included in reported capital expenditures (as a fraction) (Table 7-2)

TLC = true total land costs for new capital projects (included plus not-included land costs; expressed as a fraction of FHWA-reported capital expenditures) (Table 7-2)

As shown in Table 7-4, LNI appears to be on the order of several billion dollars annually. Since the corresponding cost already is included in the estimate of the annualized cost of all existing highway capital, the weight on LNI as a separate part of the total, in Table 7-4, is zero.

7.2.8 Bicycling, pedestrian overcrossings, railroad crossings, and other facilities

State and local governments spend a relatively minor amount of money on paths, structures, facilities, and services for cyclists and pedestrians. Technically, only the portion of this expenditure that is incurred because of highways (i.e., that would not be incurred were there no motor vehicles and highways) is attributable to motor-vehicle use. For example, the extra cost of a pedestrian overcrossing of a freeway, instead of a simple sidewalk, can be attributed to motor-vehicle use, unless one can show that an overcrossing is required regardless of the main transportation system.

The FHWA's *A Guide to Reporting Highway Statistics* (1990) instructs transportation agencies to exclude costs for sidewalks, sewers (unless an integral part of the highway system), and street lighting, and to include expenditures for overpasses, underpasses, and dam crossings, but it does not specifically mention bicycle lanes, bicycle paths, bicycle bridges and tunnels, bicycle parking, or pedestrian overcrossings. Consequently, I do not know whether most state agencies include or exclude expenditures for these items from their reports to FHWA, and so do not know exactly what adjustments, if any, I need to make to the FHWA data. It appears that, generally, if a bicycle lane or path or facility is built as part of a highway project, then the expenditure will be classified with the rest of the project expenditure, not differentiated, and that the expenditure on the entire highway project will be reported to FHWA and classified by FHWA as an expenditure on highways. However, if a bicycle facility is built, or a part of a road is striped for bicycle use, as a separate project, after a highway project is completed, then whether or not the expenditure is classified by FWHA as highway-related depends on how the expending state agency reported it. In some cases, bicycle-related expenditures probably are not reported to FHWA. For example, bicycle paths built by a park agency probably are not reported.

Technically, any expenditures for on-street bicycle lanes (including maintenance, repair, cleaning, and signage) should not be counted as expenditures related to the motor-vehicle infrastructure. The City of Davis, California -- a flat university town with fairly good weather and many more cyclists per capita than all but a handful of cities in the U.S. -- spends between 1% and 5% of its transportation budget on on-street bicycle lanes, including maintenance, repair, cleaning, administration, signing, and striping (City of Davis, 1993). I believe that nationally, expenditures on bicycle lanes are no more than 1% of total highway expenditures, not only because Davis uses cycles so intensively, but because bicycle-related expenditures on State and Federal highways, such as interstates, must be very close to zero.

By contrast, the extra cost of building a pedestrian or bicycling crossing over or under a highway, compared to building a simple sidewalk or bicycle lane, usually is properly attributable to the motor-vehicle infrastructure, and presumably is included in the *Highway Statistics* estimates. I assume that this cost is in fact included in the capital expenditures related to highways reported in *Highway Statistics*. It probably is a relatively minor expense, in any event.

Considering all of these factors, I assign 1% of the FHWA-based costs to bicycles and pedestrians, and the rest to motor vehicles. (Thus, I assume that the parameter $\frac{A_{TMV}}{A_T}$ in equation 7-14b is 0.99).

Finally, one perhaps could argue that other modes of transportation, such as rail or barge, also incur costs that they would not incur were there no motor-vehicle use and no motor-vehicle infrastructure. However, I ignore this issue, in part because I do not have any data to address it.

7.2.9 The shape of the total cost function

I assume that costs are linearly related to motor-vehicle use, so that the exponent k in equation 7-14b is equal to 1.0.

7.2.10 A check on the estimate of the annualized cost

As mentioned above, my estimate of the annualized cost of highways is based in part on FHWA data on annual expenditures for highway capital. Because this is one of the larger single cost items in this analysis, I provide here an independent check of the estimate.

If roadway capital has a life of 35 to 50 years, then at the 1991 level of capital expenditures (about $37 billion), the total replacement value of all roadway capital would be $1,300 to $1,800 billion dollars. This estimate can be compared with an estimate of total miles of roads multiplied by the current capital cost per mile (Table 7-6). As developed in some detail in Table 7-6 the capital cost per mile can range over an order of magnitude, from about $200,000/mile for minor rural collectors, to nearly $4 million/mile for urban interstates. When the cost per mile for each type of road is multiplied by the miles of the road type in place, and summed for all road types, the result is $1,550 billion. This is in the middle of the range estimated on the basis of current capital expenditures and the lifetime of roads.

7.3 ANNUALIZED COST OF MUNICIPAL AND INSTITUTIONAL OFFSTREET PARKING

7.3.1 Background

There are several types of public parking: on street and offstreet, metered and unmetered, parking for government employees, and so on. The Bureau of the Census (*Government Finances: 1990-91*, 1993; *Classification Manual*, 1992) reports annual government expenditures for some of these kinds of public parking, in a category called "municipal parking". The table below shows how the different types of public parking are classified in the Census' estimates of government expenditures, and in this social-cost analysis.

type of public parking	*cost category in Census*	*where in this report*
on street, no meters	roads	section 7.2 (roads)
on street, with meters	meters: municipal parking streets: roads	meters: this section streets: section 7.2 (roads)
priced offstreet municipal garage or lot parking	municipal parking	this section
priced offstreet institutional parking	expenditures related to particular institution	this section
unpriced (bundled) offstreet parking for government employees	general public buildings	this section
unpriced (bundled) offstreet parking for anyone	??	not counted (but probably zero)

I distinguish offstreet parking provided by the public sector from priced or unpriced parking provided by the private sector simply because in general I distinguish between public-sector goods and services and private-sector goods and services. However, some municipal parking is priced at something like marginal cost, and hence really is functionally no different from priced private-sector parking, and some probably is provided as an employee benefit, and hence is no different functionally from bundled private-sector parking. (Note that since I am counting these public parking costs as a public expenditure related to motor-vehicle use, I count any payments of parking fees as a user payment, in Report #17.)

First, I estimate the annualized cost of municipal parking facilities, on the basis of Census-reported annual expenditures. For comparison, I estimate annual parking revenues received by local governments. Then, I estimate the cost of institutional parking. Finally, I estimate the cost of unpriced public parking for public employees.

7.3.2 The cost of local government parking facilities

Expenditures by local governments. From fiscal year 1989 through fiscal year 1992, local governments spent about $0.8 billion per year for the provision, construction, maintenance, and operation of local government parking facilities (public parking lots and garages, and parking meters on-street and in lots) operated on a commercial basis (Bureau of the Census, *Government Finances*, various years; Bureau of the Census, *Classification Manual*, 1992) . This amount is very close to the amount received in revenues (see below). Of the $0.8 billion spent by local governments, $0.3 billion was for capital outlay, and $0.5 billion was for current operation. Assuming a discount rate of 3-7% (same as for highways), a life of 35-45 years (same as for private parking; see Report #6), true land costs of 25% of capital expenditure (based on the cost estimates for private parking, in Report #6), and reported land costs about 25% less than true land costs, the annualized capital replacement cost would be $0.5 to 1.0 billion per year (equation 7-7). The total annualized cost -- annualized capital replacement cost plus operating and maintenance cost -- thus would be about $1.0 to $1.5 billion per year. According to the Census, Federal and state government spent nothing on parking.

The Census estimates do not include expenditures for the enforcement of parking regulations (counted by the Census as an expenditure for police protection), for parking facilities for the exclusive use of government employees (counted by the Census as an expenditure on general public buildings), or for parking facilities connected to a specific type of facility, such as a sports stadium (counted by the Census as an expenditures for the specific type of facility) (Bureau of the Census, *Classification Manual*, 1992). As noted above, I cover these costs elsewhere: enforcement costs are counted as police costs; the cost of parking facilities for government employees is estimated below; and the cost of parking at institutions also is estimated below.

However, it is possible that the Census data under-represent expenditures in smaller cities. As mentioned below, the Census does believe that it underestimates revenues received by municipal parking operators.

Revenues from parking charges. In fiscal year 1989-1990, local governments received $0.854 billion in parking charges (Bureau of the Census, *Government Finances: 1989-90*, 1991) and in fiscal year 1990-1991, they received $0.924 billion (Bureau of the Census, *Government Finances: 1990-91*, 1993)[8]. These revenue figures exclude local parking taxes (Hirsch, 1993).

The parking revenues shown here definitely include all revenue from facilities owned and operated by local governments, and *might* include revenues from facilities that are owned by the local government but leased out to a private operator. Whether or not parking receipts at a municipally owned but privately operated parking facility are counted as local-government parking revenue depends on how the local government reports (to the Census) the money it gets from the private lessor of the facility. (The

[8]Of this total for fiscal year 1990-91, cities received $0.729727 billion, and counties received the remainder (Hirsch, 1992). In 1989-90, cities received $0.672754 billion in parking revenues

Census does not give specific instructions to the survey respondents.) If the local government reports the receipts from the private operator as rent, then it is likely that the Census has classified the receipts under rental income and not under parking. However, if the local government notes that the rental income is from a parking facility, the Census might have classified the revenues under parking (Hirsch, 1993). It is possible, then, that the Census' estimate of parking revenues to local governments (in the *Government Finance* series) and its estimates of parking revenues to commercial facilities (in the *Service Annual Survey* series) double count some of the parking receipts at facilities owned by local governments but operated privately. My impression, though, is that any such double counting is likely to be small.

The Census notes that its estimate of local parking revenues received might be an underestimate, because some smaller localities might be under-reporting or not reporting parking revenues. To check the Census figures, I obtained from city and state controller's offices in New York and California estimates of total parking revenues in their states, and compared the estimates with the Census' estimates for New York and California (Table 7-7.). The comparison of Table 7-7. shows that the Census data are reasonably close to the state data. However, the Institutional and Municipal Parking Congress (IMPC, 1992) also reports parking revenues from some municipalities, as well as from universities, airports, and hospitals. Their data, extrapolated to a national level, indicate revenues of around $2 to $3 billion. It thus is possible that the Census does indeed underestimate local parking revenues.

If the revenues received by municipal parking authorities bear any sort of normal market relation to cost, then the annualized cost of municipal parking must be at least $1 billion per year. Of course, municipalities might not charge market prices, or might not charge for parking at all, in which case the estimates of revenues tell us little about the total cost.

An estimate of the total. On the basis of the foregoing data on expenditures and revenues, I estimate that the annualized cost of all local government parking operated on commercial basis is $1 to $2 billion per year, excluding parking taxes.

7.3.3 The cost of institutional parking

I classify as public parking all parking provided at a price by universities, hospitals, airports, and sporting facilities, even though some of these institutions (e.g., some universities) are private. Table 7-8 shows the revenues from and cost of priced parking at institutions. The Institutional and Municipal Parking Congress (IMPC) reports parking revenues from its member universities, hospitals, and airports. I have scaled their reported revenues to national levels, for all such institutions (Table 7-9) To this I add an estimate of revenues from parking at sporting facilities, on the basis of data reported by the Census. Finally, I deduct estimated producer surplus, as indicated in Table 7-8, to arrive at the total economic cost of institutional parking

7.3.4 Unpriced parking for public and institutional employees

As noted above, the Census' estimates of parking expenditures by municipalities pertain only to facilities operated on a commercial basis; they do not include expenditures on parking provided free to public employees. Similarly, the estimate above of the cost of institutional parking is based on parking revenues, and hence does not include the cost of any unpriced institutional parking. Therefore, I must estimate separately the cost of unpriced public and institutional parking.

I estimate the cost as:

$$AC_{Public} = \frac{P \cdot \left(FL \cdot ACL + (1 - FL) \cdot ACG\right)}{1000000000} \qquad \textbf{[7-16]}$$

AC_{Public} = the annualized cost of unpriced, offstreet, nonresidential parking places for public employees the U. S. in 1990/1991 (10^9 \$/year)

P_{Public} = number of offstreet nonresidential unpriced parking spaces for public employees in the U.S. in 1990/91 (see below)

FL = fraction of spaces that are lots, as opposed to garages (use estimate from Report #6)

ACL = the annualized cost (including the cost of land) of an offstreet, nonresidential place in a parking lot ($/year/space) (use estimate from Report #6)

ACG = the annualized cost (including the cost of land) of an offstreet, nonresidential place in a parking garage ($/year/space) (use estimate from report #6)

I will estimate the amount of unpriced parking for public and institutional employees (P_{Public}) on the basis of employment. In 1991, government employed 18.4 million persons, out of 108.2 million non-farm employees (Bureau of Labor Statistics, 1994). The 18.4 million includes employees of public but not private schools, hospitals, and airports. However, because I am counting all university, hospital, and airport parking here, in this report, I must expand the 18.4 million to include employees of private universities, hospitals, and airports. I assume that the relevant public+institutional workforce is 20% of the total workforce, and, therefore, that the number of free employer-provided parking spaces for them is 20% of the total number of free employer-provided spaces estimated in Report #6 (about 82 million).

With this estimate of the number of spaces, and values for the other parameters taken from Report #6 as indicated above, I estimate the annualized cost to be $8 to $15 billion.

Finally, I assume that there is very little unpriced, non-employee public parking, and so do not attempt to estimate the cost.

7.3.5 The total cost of municipal and institutional parking

The cost estimates for 1991 are summarized as follows (10^9 1991$, excluding parking taxes):

	Low	High
Priced parking provided by local governments, 1991	1.00	2.00
Priced parking at universities, hospitals, and airports, 1990/91	2.51	2.51
Priced parking at other institutions, 1991	0.09	0.09
Unpriced public parking provided to public employees, 1991	8.32	15.16
Unpriced public parking provided to all others, 1991	n.e.	n.e.
Total	*11.92*	*19.76*

The data and estimates discussed above apply to the year 1991. To estimate costs for other years, I assume that cost is proportional to the number of vehicles and to the cost of parking spaces. Specifically, I estimate the cost of municipal and institutional parking for any year Y by scaling the 1991 estimates by the ratio of total U. S. vehicle registrations in year Y to registrations in 1991 (FHWA, *Highway Statistics*, various years) and by the ratio of the year-Y to year-1991 Producer Price Index for highway and street construction (data from Bureau of Labor Statistics, www.bls.gov).

7.4 HIGHWAY LAW ENFORCEMENT AND SAFETY, AND OTHER POLICE PROTECTION COSTS RELATED TO MOTOR-VEHICLE USE

7.4.1 Background

Many of the crimes committed in the U.S. are related in one way or another to the use of motor vehicles. People steal motor vehicles, steal things from motor vehicles, rob service stations, set fire to motor vehicles, kill while stealing a motor vehicle, drive while drunk, hit and run, and commit other driving or motor-vehicle-regulatory offenses. When a crime is reported to the police, the police usually investigate it, and this investigation costs police time and resources. As a case proceeds through the justice system, it gives rise to more costs: if the police make an arrest, additional police costs; if a case goes to court, judicial and legal costs; and if an accused person is convicted, correctional-system costs. Every year, government spends many billions of dollars on the entire criminal justice system: in fiscal-year 1990-91, Federal, state, and local government spent $38.9 billion for police protection, $19.4 on the judicial and legal system, and $29.3 on corrections -- a total of $87.6 billion (Table 7-1). As we shall see, a nontrivial fraction of this total is related to motor-vehicle use.

I could not find any source which estimates *all* expenditures on police protection related to motor-vehicle use[9]. However, FHWA, as part of its data collection effort for the *Highway Statistics* report, does ask state and local governments to estimate expenditures for highway law enforcement and safety (see below). It turns out that the FHWA estimate does indeed include most -- but not all -- of what in the end I estimate to be total police-protection expenditures related to motor-vehicle use. Given this, I will estimate total police costs related to motor-vehicle use as:

FHWA-estimated highway law enforcement and safety costs plus the motor-vehicle-related portion of other (not-estimated-by-FHWA) police costs reported by the Bureau of the Census.

To estimate the motor-vehicle related portion of other (non-FHWA-estimated) police costs, I first deduct from the Census estimates of total police expenditures those expenditures that already are included in the FWHA estimates. Then, I specify the activities (offenses, arrests) that are related to cost in the total cost function (equation 7-8), and estimate the shape of the function by estimating the exponent k. Finally, I estimate the motor-vehicle-related share of total offenses or arrests, and calculate the motor-vehicle cost via equation 7-14.

The bulk of the effort here is estimating the motor-vehicle-related share of crimes or arrests. Note that my estimate of this share accounts for the possibility of “substitutes” for crimes that nominally are related to motor-vehicle use. (This is explained further below.)

The method and results are summarized immediately below, and documented in the following sections.

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[9]We asked several agencies to try to estimate national costs associated with motor-vehicle use or determine how officers spend their time on average. Not surprisingly, none were willing. We did not survey local police departments because we were not convinced that the information that we would have gotten would have resulted in an estimate that would have been better than one based on reported crimes and arrests.

	Costs in 1991 (10^9 $, except as noted)	Low	High
1.	*FHWA-estimated costs: annualized capital and O & M costs of highway law enforcement and safety related to motor-vehicle use, estimated from FHWA expenditure data (using equation 7-14b)*	*7.41*	*8.67*
2.	Total annualized capital and O&M cost of all police protection, including highway law enforcement and safety, estimated from Census data (equation 7-7; see discussion below)	41.49	46.75
3.	Fraction of FHWA expenditures included in Census police expenditures (see discussion below)	0.90	0.80
4.	Total police costs potentially related to motor-vehicle use, and not included in FHWA-based estimates ($2 - 1 \times 3$)	34.82	39.81
5.	Fraction of line 4 total that is a cost of motor-vehicle use (including allowance for substitute crimes) (see discussion below)	0.037	0.119
6.	*Police expenditures that are an opportunity cost of motor-vehicle use, in addition to costs estimated from FHWA data (equation 7-14a)*	*0.85*	*4.06*

7.4.2 FHWA estimates of expenditures for highway law enforcement and safety

The FHWA instructs state and local governments to estimate disbursements for the enforcement of highway laws and ordinances, traffic supervision, highway and traffic safety, driver education, vehicle inspection, and enforcement of vehicle size and weight limits (FWHA, *A Guide to Reporting Highway Statistics*, 1990). In 1991, these estimated expenditures totaled $7.0 billion (Table 7-3) -- about 20% of the total police expenditures reported by the Census[10].

I use equation 7-14b to estimate the total annualized cost of highway law enforcement and safety. I assume that all parameters except ACE, OME, $\frac{A_{TMV}}{A_T}$, and k have the values assumed or estimated for "other [non-FHWA] police costs," as discussed below and shown in Table 7-2. To estimate ACE (annual capital expenditures -- the FHWA does not distinguish capital expenditures for the highway patrol from operations, administration, and maintenance expenditures from the highway patrol), I assume that the ratio of capital expenditures to total expenditures for highway law enforcement and safety is the same as this ratio for all state police expenditures, averaged for fiscal years 1991 and 1992 (6.5%; Table 7-1). Highway patrol operations, administration, and maintenance expenditures (OME) then are the difference between total reported expenditures and estimated capital expenditures. The motor-vehicle-

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[10]This 20% figure is consistent with data on arrests. Presumably, a large fraction but certainly not all of the FHWA-estimated expenditure is related to DUI and other traffic offenses. In 1991, 1.8 million people were arrested for DUI (FBI, *Crime in the United States 1991*, 1992a), and about 0.5 million were arrested for other traffic violations (My estimate; see notes to) -- a total of 2.3 million, or 16% of the 14.2 million persons arrested in 1991.

related fraction of total highway law-enforcement and safety costs ($\frac{A_{TMV}}{A_T}$) presumably is 1.0.

The exponent k determines the shape of the function that relates cost (highway law enforcement and safety expenditures) to activity (motor-vehicle use). As discussed in sections 7.1.4 and 7.4.5, to the extent that there is a "capacity requirement" for the highway patrol that is relatively insensitive to the amount of motor-vehicle use, then long-run marginal costs decrease with increasing activity, and k is less than 1.0. As discussed in section 7.4.5, it is likely that in the cost function for general patrol activities, k is less than 1.0. However, general patrol is by no means a pure or even nearly public good (in which case k would be zero); rather, it must depend in some way on the type and quantity of the activity being patrolled. Furthermore, the cost of investigation, enforcement, administration, and the like must be more or less proportional to the number of incidences (violations, crimes, or arrests) and hence to motor-vehicle activity. Both of these points are discussed a bit more in regards to the shape of the total cost function for other (non-FHWA-estimated) police activities, in section 7.4.5. Nevertheless, because highway law enforcement and safety presumably involves more "general" patrol than does other police work, I assume that highway law enforcement and safety costs are a little less sensitive to activity than other costs are -- that is, that the exponent k in the cost/activity function for highway law enforcement and safety is slightly less than the exponent k in the cost/activity function for other police work. My assumptions are shown in 7-2.

The FHWA estimate of highway law enforcement and safety expenditures does not include any costs incurred due to motor-vehicle related crimes: *A Guide to Reporting Highway Statistics* (FHWA, 1990) specifically states that the "costs of criminal investigations and general policing activities should not be shown [under highway police and safety]." Thus, police costs associated with, say, motor-vehicle thefts, are not included in the FHWA estimates. These other costs, not included in the FHWA estimates, must be estimated with respect to the total police-protection expenditures reported by the Census.

7.4.3 Deduct from the Census estimates police expenditures reported to FHWA

To estimate the police-protection expenditures not covered in the FHWA estimates, I compare the FHWA estimates with the Census estimates, and deduct from the Census estimates of total police-protection expenditures the overlap between the FHWA and the Census estimates.

It appears that most of the police and safety expenditures reported to FHWA are included in the Census' estimates of total police expenditures. The Census' category "police protection" includes expenditures for, among other things: regular law-enforcement activities of police; state highway patrols; buildings used exclusively for police purposes; and vehicle inspection and regulation, the enforcement of liquor laws, and traffic control, and traffic engineering, *if* these were handled by a policy agency (Bureau of the Census, *Classification Manual*, 1992; emphasis in original). Comparing the

Census coverage with the FHWA coverage described above, we see that the major difference is that the FHWA estimates may include expenditures for vehicle inspection, traffic control, and similar activities *not* performed by a police agency, whereas the Census estimates definitely do not. Also, the FHWA estimates include expenditures for driver education, whereas the Census estimates do not. However, the disjunction is likely to be small compared to the overlap[11]. For example, most of the $4-5 billion spent by states for police is for the highway patrol (Bureau of the Census, *Government Finances 1990-91*, 1993), which suggests that expenditures for the highway patrol, which are included in both the FHWA and the Census estimates, are more than half of the total police expenditures reported to the FHWA. Therefore, I have assumed that 80-90% of the total highway police and safety expenditures reported to the FHWA are included in the Census estimates of total police expenditures[12].

7.4.4 The "activities" related to expenditures on police protection (other than highway law enforcement and safety)

Police expenditures are a function of the time and resources devoted to preventing and investigating crime. Because the average amount of time devoted to a motor-vehicle-related crime might be more or less than the amount devoted to other

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[11]This presumes that state and local governments estimate all of the cost items that FWHA asks for, and none of the crime-related costs that FHWA says to exclude. Of course, these assumptions may not be right: contacts at the FHWA and at state and local governments told me that the estimated disbursements for highway law enforcement and safety are among the least reliable of all the FHWA estimates. FHWA does not oversee or check in detail the local estimates of disbursements for highway law enforcement and safety, and consequently does not know how reliable they are.

[12]Ideally, one would disaggregate total police-protection expenditures into expenditures for specific police activities, and then estimate the motor-vehicle cost share of each sub-expenditure area. However, I do not know how total police costs break down nationally, and even if I did, it would be difficult to estimate motor-vehicle cost-shares specifically for each expenditure sub-area. If there actually are large expenditure sub-areas that are not related to motor vehicle use, then I might overestimate the motor-vehicle share of police-protection expenditures in this report. But the reverse also is true. I do not know if my estimates are biased in this way.

However, the Census expenditures *are* reported separately for the federal government, state governments, and local governments. In the Census totals, the police-protection expenditures by the federal government are for the Federal Bureau of Investigation, the Customs Service, the Drug Enforcement Agency, the Bureau of Alcohol, Tobacco, and Firearms, and the Secret Service. Because few if any of the activities of these agencies are plausibly related to motor-vehicle use, one could argue that I should deduct all Federal police-protection costs from the total cost to be allocated, and also deduct federally investigated crimes from the total amount of offenses and arrests. However, it is impossible to estimate and therefore deduct federally investigated crimes, which are included in the total offense and arrest statistics reported by the FBI (1992a). Therefore, I leave the cost of federal police agencies in the total cost to be allocated to motor-vehicle use, and leave federally investigated offenses and arrests in the measure of total arrests and offenses. That little of the cost of federal police agencies should be allocated to motor-vehicle use is handled by assuming zero motor-vehicle-related fractions in the major areas of federal police activities (e.g., drugs, counterfeiting).

crimes, it would be best, in principle, to relate police expenditures to the total police time spent on the various kinds of crimes. However, there are no such data on police time by specific type of crime, and no way of estimating whether the time per motor-vehicle-related crime is more or less than the time per other kind of crime.

Instead, we must relate police expenditures to the mere number of offenses (specifically, Crime-Index offenses) or arrests. I will use both measures, because they give different "weights" to police time: crimes that resulted in arrests presumably have required more police resources than have crimes that have not.

7.4.5 Shape of the total-cost function for police protection (other than highway law enforcement and safety)

In this section, we will attempt to determine the relationship between criminal activity, as measured by offenses or arrests, and expenditures on police protection (other than highway law enforcement and safety). As a starting point, we can ask if expenditures are related linearly to activity (in which case the exponent k in equations 7-8 and 7-14 equals 1.0), or if instead marginal costs decrease with increasing activity ($k < 1.0$).

It is doubtful that all expenditures on police protection are related linearly to offenses or arrests, because there must be some "capacity requirements" (see section 7.1.4) that tend to make reductions in criminal activity result in less-than-proportional reductions in police expenditures -- in other words, that tend to make the shape exponent k in equation 7-8 less than 1.0. In the case of police services, these capacity effects can be discussed as quasi-public goods.

For example, general patrol, if it is not directed at a specific activity or specific group of people, and instead is intended primarily to deter crime generally, can be considered to be a quasi-public good. Patrol that would occur regardless of the type or quantity of criminal activity can not be considered to be even a long run cost of any particular type of criminal activity.

But exactly how much police activity and expenditure is "general," meant mainly to be a deterrent, and hence more or less independent of criminal activity? Although I do not address this question formally, I suspect that such "general" police activity is a minor albeit not completely trivial fraction of the total.

In the first place, even general patrol is not necessarily a public good. Police attention often is a scarce resource. Police patrol is not like strategic national defense: police, unlike missiles, deter not because they merely exist (if this were the case, police patrol *would* be entirely a public good), but because they actively look and scout. The policeman watching for motor-vehicle theft is, in that instant, not watching for something else. The policeman patrolling an area where lots of motor-vehicle thefts occur is not available to patrol another area. In general, if the police have fewer things to worry about -- say, because there are fewer motor-vehicles around to be stolen -- then either we will need fewer police to worry about the remaining things, or else the police will do a better job watching the remaining things. In any case, there is no free lunch. If in response to less motor-vehicle use we have the same amount of policeman, but more patrol work in other areas, then the cost of the motor-vehicle use is this other work foregone.

Furthermore, the investigative and administrative services of police are not public goods at all, but rather presumably are closely related to the number of reported offenses or arrests. The policeman writing up the motor-vehicle theft report is not writing up another case. The office space taken up by the policeman working on the motor-vehicle theft is not available to other policeman. The person doing the payroll for the policeman working on the motor-vehicle theft is not available to do other work. If after a change in motor-vehicle use we have fewer crimes, then we will need fewer policeman for investigation, enforcement, reporting, follow-up, testimony, administration, and so on. And, then, in the long run, we will need less building space, utilities, and so on.

I believe that, for the most part, police costs are proportional in fine detail to the amount and type of criminal activity. Thus, my assumption for k, shown above, assumes only a modest trend of decreasing marginal costs with activity -- that is, that k is less than 1.0, but not dramatically less[13].

7.4.6 The motor-vehicle-related fraction of the cost-relevant activity: methods and data

General methods. In this section, I estimate the motor-vehicle-related share of the total offenses or arrests -- the fraction $\frac{A_{TMV}}{A_T}$ in equation 7-14a. Because the activity measures in this section relate to crime, I will use CMV* to represent total motor-vehicle-related offenses or arrests (instead of the generic A_{TMV} in the ratio $\frac{A_{TMV}}{A_T}$), and CT* to represent all offenses or arrests (instead of the generic activity total A_T). I will call the ratio $\frac{CMV^*}{CT^*}$ the motor-vehicle related crime fraction, CFMV*.

Total motor-vehicle-related offenses or arrests, CMV*, are those that would not occur were there no motor-vehicle use. I will estimate this quantity in two parts. First, I estimate offenses or arrests *nominally* related to motor-vehicle use. (For clarity, I denote this nominal total CMV, to distinguish it from CMV*.) These "nominally" related

[13]It is important to get the shape roughly right, because total expenditures on police are relatively large. To support the proposition that most police services are not public goods, and that in fact a sizable chunk of total police resources are an economic cost of motor-vehicle use, I point out that one can imagine that there could be two different kinds of police, with different buildings and personnel and administration and budgets: those concerned only with motor-vehicle related crimes, and those concerned with all other crimes. To the extent that the motor-vehicle police had activities (including such things as writing different reports) *different* from those of the other police, and did not jointly produce non-motor-vehicle security with motor-vehicle security, the associated police resources would be a separable, long-run cost of motor-vehicle use only. It seems clear to me that one could indeed create a separate motor-vehicle police department with distinct activities and only a modest joint production of motor-vehicle and non-motor-vehicle security.

offenses or arrests or those that appear in some way, by name, to involve motor vehicles, directly or indirectly. For example, a robbery in a parking lot is nominally related to motor-vehicle use, because motor-vehicles use parking lots. Drunk driving, motor-vehicle theft, and larceny theft from motor vehicles also are nominally related to motor-vehicle use. Table 7-10 shows all the crimes nominally related to motor-vehicle use in this analysis.

Of course, one sees right away that the elimination of motor-vehicle would not reduce crimes by the number *nominally* related to motor-vehicle use, because criminals would find substitutes for many of these nominally motor-vehicle related crimes. For example, even though the elimination of parking lots would, ipso facto, eliminate robberies in parking lots, it would not on balance reduce the total number of robberies by the number that would have occurred in parking lots, because some of the robberies that would have happened in parking lots will happen in other places. Therefore, because the objective is to estimate crimes or arrests that would not occur were there no motor-vehicle use, we need to exclude from our estimate those nominally motor-vehicle related crimes for which there are substitutes, so that we are left only with the crimes for which there are no substitutes. Continuing with the example of robberies in parking lots, we need to exclude from total robberies in parking lots the number that we think would occur elsewhere were there no motor-vehicle use and hence no parking lots.

This accounting for substitute crimes is the second part of the estimation of CMV*. Specifically, I multiply the number of crimes nominally related to motor-vehicle use by the fraction for which there are no substitutes. Thus, if there would be substitutes for 80% of parking-lot robberies, then for 20% there would be no substitutes -- that is, only 20% of the parking-lot robberies would be eliminated on balance, if motor-vehicle use were eliminated -- and so the final motor-vehicle-related total would be equal to $CMV_{PLR} \cdot 0.20$, where PLR = parking-lot robberies.

Formally:

$$CFMV^* = \frac{CMV^*}{CT^*}\left(\equiv \frac{A_{TMV}}{A_T}\right) \qquad \textbf{[7-17]}$$

$$CMV^* = \sum_c CMV_c \cdot S_c \cdot \frac{NFHWA_c}{100} \qquad \textbf{[7-18]}$$

$$CT^* = CTI - \sum_c CMV_c \cdot \left(1 - \frac{NFHWA_c}{100}\right) \qquad \textbf{[7-19]}$$

where:

CFMV* = the motor-vehicle-related fraction of total crimes, excluding crimes covered in the FHWA estimates of police expenditures

CMV* = total motor-vehicle related crimes (offenses or arrests), excluding crimes for which there are substitutes, and crimes covered in the FHWA estimates

CT* = total crimes (offenses or arrests), excluding crimes that are included in the FHWA estimates

subscript c = specific crimes nominally related to motor-vehicle use (Table 7-10)

CMV_C = Number of crimes (offenses or arrests) of type C nominally related to motor-vehicle use (Table 7-10)

S_C = of crimes C nominally related to motor-vehicle use, the fraction for which there are no substitutes (Table 7-10)

$NFHWA_C$ = of crimes C nominally related to motor-vehicle use, the fraction not covered in the FHWA estimates of police expenditures (Table 7-10)

CTI = total crimes (crime-index offenses or total arrests)

The values of the parameters in equations 7-18 and 7-19 are discussed next.

Total offenses or arrests (CTI). The FBI (1992a) reports "Crime Index" offenses, and total arrests for all offenses. The Crime Index covers the violent crimes of murder, non-negligent manslaughter, forcible rape, robbery, and aggravated assault, and the property crimes of burglary, larceny-theft, motor-vehicle theft, and arson. The arrest data, however, cover all offenses, not just those covered by the Crime Index.

In this analysis, total offenses are equal to total reported Crime-Index offenses (14.87 million) plus estimated arson offenses (0.0998 million) in 1991 (FBI, 1992a). Total arrest are equal to the 14.21 million arrests in 1991 for all criminal infractions except traffic violations (FBI, 1992a, p. 212)[14] , plus my estimate of arrests for traffic crimes other than hit and run (see below).

Offenses and arrests nominally related to motor-vehicle use (CMV_C). These are estimated in the following crime categories (c):

1. Murder of police during traffic stop
2. Murder during MV theft
3. Murder during robbery of gas station
4. Rape in parking lot or garage

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[14]Note that the number of arrests is not equal to the number of crimes cleared by arrests. According to the FBI (*Crime in the United States*, 1992a, p. 202): "For UCR [Uniform Crime Reports] purposes, law enforcement agencies clear or solve an offense when at least one person is arrested, charged with the commission of the offense, and turned over to the court for prosecution. Clearances recorded in 1991 may be for offenses which occurred in prior years. Several crimes may be cleared by the arrest of one person, while the arrest of many persons may clear only one offense".

5. Robbery of gas station

6. Robbery in parking lot, garages, etc.

7. Robbery of motor vehicles (“car-jackings”)

8. Theft of automobiles and motorcycles

9. Theft of trucks and buses

10. Larceny theft from MV

11. Larceny theft of MV accessories

12. Arson to motor-vehicles

13. Arson to gas stations and car dealerships

14. Driving under the influence

15. Hit and run

16. Other traffic violations

17. Fraud, receiving stolen property, and other crimes, not covered above, related to motor-vehicle use

Offenses nominally related to motor-vehicle use in 1991

1 In 1991, 13 law-enforcement personnel were killed during traffic pursuits or stops (Bureau of Justice Statistics, *Sourcebook of Criminal Justice Statistics 1992*, 1993). During the 1980s the average was about 12 per year.

2 Calculated as: 52 murders reported during motor-vehicle theft, multiplied by a factor to account for murders in which the circumstances were not known. This factor is equal to the ratio of total murders to murders with circumstances reported (24,703/15,913; FBI, 1992a).

3 I assume that 2.6% of 2,201 reported murders during robbery happened at a gas station, because 2.6% of all robberies were of service stations (see below); then I scale the results by the ratio of total murders to murders with circumstances reported (24,703/15,913), as above (FBI, 1992a).

4 According to the National Crime Victimization Survey (Bureau of Justice Statistics, *Criminal Victimization in the United States*, *1991*, 1992), 4.2% of all rapes occurred in parking lots or garages. I assume this percentage applies to the 106,593 rapes reported to law-enforcement agencies for 1991(FBI, 1992aJ).

5 From the FBI’s (1992a) Table 7.

6 According to the National Crime Victimization Survey (Bureau of Justice

Statistics, *Criminal Victimization in the United States, 1991*, 1992), 11.9% of all robberies occurred in parking lots or garages. I assume this percentage applies to the estimated 687,732 total robberies (FBI, 1992a).

7 I use the FBI's estimate of reported carjackings in 1991 (FBI, 1992b). I assume that in the Uniform Crime Reports, a carjacking is reported as a robbery rather than a motor-vehicle theft. If carjacking actually is classified as motor-vehicle theft, then I have double counted, because I count all motor-vehicle thefts in a separate line in this table. However, the FBI [1992b] states that most law-enforcement agencies classify carjacking as robbery. Moreover, any potential double counting is not serious, because there are almost 100 times more motor-vehicle thefts than carjackings.)

8-9 The FBI (1992a) reports total motor-vehicle offenses (1,661,738 in 1991), and the percentage distribution by type of vehicle: 79.7% automobiles; 14.7% trucks and buses; 5.6% other. I assume that half of the 5.6% "other vehicles" are motorcycles, and that the remainder are things such as snowmobiles which the FBI counts as a motor-vehicle but which I don't.

10 From the FBI's (1992a) Table 7

11 From the FBI's (1992a) Table 7

12 Calculated as: 21,917/86,147 · 99,784, where 21,917 is the number of motor-vehicle arsons reported to the FBI by law-enforcement agencies; 86,147 is the number of arsons in which the type of property was reported to the FBI; and 99,784 is the number of arsons reported to law-enforcement agencies (including those for which the type of property was not reported to the FBI) (FBI, 1992a).

13 Calculated as: 5,226/86,147 · 99,784 · 0.05, where 5,226 is the number of arsons to "other commercial property," 86,147 and 99,784 are as above, and 0.05 is what I assume is the ratio of car-dealership and gas-station arsons to "other commercial property" arsons.

14-17 Not estimated. The Crime Index and the Uniform Crime Reports do not report DUI, hit and run, fraud, embezzlement or other motor-vehicle offenses (such as traffic violations). Thus, these are omitted from both the numerator and the denominator of CFMV* based on Crime-Index offenses.

Persons arrested for crimes nominally related to motor-vehicle use in 1991

1-3 Equal to the number of offenses, from above, multiplied by the ratio of all persons arrested for murder to all reported murder offenses (24,050/24,703) (FBI, 1992a)

4 Equal to the number of offenses, from above, multiplied by the ratio of all

persons arrested for rape to all reported rape offenses (40,120/106,593) (FBI, 1992a)

5-7 Equal to the number of offenses, from above, multiplied by the ratio of all persons arrested for robbery to all reported robbery offenses (173820/687,732) (FBI, 1992a)

8-9 Equal to the number of offenses, from above, multiplied by the ratio of all persons arrested for motor-vehicle theft to all reported motor-vehicle offenses (207,700/1,661,738) (FBI, 1992a)

10-11 Equal to the number of offenses, from above, multiplied by the ratio of all persons arrested for larceny theft to all reported larceny-theft offenses (1,588,300/8,142,228) (FBI, 1992a)

12 Equal to the number of reported motor-vehicle arsons cleared by arrest (1,922), multiplied by the ratio of all persons arrested for arson (20,000) to all reported arson offenses cleared by arrest (15,548) (FBI, 1992a)

13 Equal to the number of reported arsons to "other commercial" property cleared by arrest (781), multiplied by the motor-vehicle related percentage of arsons to other commercial property (I assume 5%, as above) multiplied by the ratio of all persons arrested for arson to all reported arson offenses cleared by arrest (20,000/15,548) (FBI, 1992a)

14 From the FBI (1992a).

15-16 There are no national data on arrests for hit and run, or other traffic crimes (There are two types of hit and run crimes: with injury and without. The former is a violent crime and the latter is a property crime.) However, I do have data on arrests for these crimes in California: in 1991 arrests for hit and run were 0.4% of total arrests in California, and arrests for other traffic crimes were 3.6% of total arrests (Office of the Attorney General, 1992). However, arrests for motor-vehicle related crimes *excluding* hit and run and other traffic crimes was a slightly larger percentage of total arrests in California than in the whole nation (20% versus 18%). If the same was true of hit and run and other traffic offenses -- that is, if arrests for hit and run and other traffic crimes was the same slightly larger percentage of total arrests in California than in the whole nation -- then I should multiply the California percentages (0.4% and 3.6%) by 18/20 in order to derive national totals. I have done this here to estimate arrests for hit and run and for other traffic crimes.

17 I assume that arrests for fraud or embezzlement involving the motor-vehicle business, and for receiving or possessing stolen motor-vehicles, are 5% of all arrests for fraud, embezzlement, or receiving or possessing stolen property (611,800; FBI, 1992a).

Note that the FBI arrest data cover all offenses, not just the Crime Index offenses of the Uniform Crime Report. See also the notes to Table 7-10, and Table 7-11.

Of crimes nominally related to motor-vehicle use, the fraction for which there are no substitutes. (S_C). This fraction varies considerably from crime category to crime category. In some cases, it is easy to estimate. For example, it seems reasonable to argue that there are no direct substitutes for hit and run, drunk driving, and traffic violations, and hence that all of these nominally motor-vehicle related crimes are in fact properly (uniquely) attributable to motor-vehicle use. I therefore assume that 100% of these crimes have no substitutes, and are entirely attributable to motor-vehicle use.

However, some of the other crimes that nominally involve motor vehicles -- namely homicide, robbery, motor-vehicle theft, larceny theft, and arson-- might be spurred not by something unique about motor vehicles, but rather by thrill, desperate need, or plain pathology. These would be instances of criminal behavior that presently happen to "involve" motor vehicles or motor-vehicle infrastructure, but that might occur anyway even if there were no motor vehicles or motor-vehicle infrastructure. In general, whether or not criminals who commit crimes nominally related to motor-vehicle use would commit other crimes even if there were no motor vehicles depends on the motivation of the criminal, and the risks and benefits of committing a crime nominally related to motor-vehicle use compared to committing a crime not so related (Stigler, 1970). At the opposite end of the spectrum from drunk driving and hit-and-run, most of the rapes, robberies, and thefts[15] that now occur in parking lots might occur anyway (in, say, alleys or parks), even if there were no parking lots. Thus, eliminating motor-vehicle use would reduce total rapes, robberies, and thefts not by the number now committed in parking lots, but rather by some much smaller number.

This problem is complicated, and cannot be analyzed in detail here. I reiterate, though, that a large fraction of the costs estimated here are due to crimes that arise uniquely from the *use* of motor vehicles -- i.e., crimes that certainly would not occur if there were no motor vehicles. Moreover, at least some of the other crimes that nominally involve motor vehicles would be eliminated if motor vehicles were eliminated. Consider motor-vehicle theft, presumably one of the more costly of the crimes nominally related to motor-vehicle use. According to the FBI (1992b), thieves steal cars for several reasons: to part out the components of the car; to re-tag the car and use it for transportation; to export the vehicle to a foreign country; to collect on insurance (the thieves often are in cahoots with the vehicle owners, as part of an insurance scam); and to use the car to commit or get away from a crime. Considering these motivations and opportunities, I believe that at least some criminals would not find satisfactory substitutes for the theft of motor vehicles, and hence that there would be fewer crimes of theft were there less motor-vehicle use.

In light of this, I have multiplied the total number of reported motor-vehicle related crimes (offenses or arrests) by the fraction for which there are no substitutes, which also can be understood as the fraction of the reported crimes that would not have

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[15]It is worth noting that fully one-third of all crimes of "personal larceny without contact" occur in a parking lot or a garage (BJS, *Criminal Victimization in the United States, 1991*, 1992).

occurred, on balance (after substitution) had there been no motor-vehicle use (Table 7-10). I have estimated different weights for different crimes, because, as mentioned above, whether or not a crime not nominally related to motor-vehicle use would be substituted for a crime nominally related to motor-vehicle use depends on the crime.

To summarize: the weights of Table 7-10 are my estimates of the fraction of the total number of instances of each general type of crime (murder, robbery, theft, arson) that would in fact be eliminated altogether were there no motor-vehicle use. For example, a weight of 10% on gas-station robberies means that I assume that, were there no motor vehicles (and hence no gas stations), the total number of robberies would be reduced by 10% of the number of gas-station robberies. Thus, only 10% of gas station robberies would be an opportunity cost of motor-vehicle use. For the rest of the gas station robberies, there are, I assume, substitutes.

Several of these estimates are little more than guesses. Obviously, more research in this area is needed.

Fraction not included in police expenditures reported to FHWA ($NFHWA_C$). Because the purpose here is to calculate the motor-vehicle share of police expenditures *excluding* those expenditures for highway law enforcement and safety already estimated by FHWA, I must count only those arrests and offenses not already covered under FHWA's category of "highway law enforcement and safety."

If the FHWA gets the data that it asks for (see above), then all crimes of murder (except perhaps murder of police officers), rape, robbery, theft, arson, and fraud etc. (see Table 7-10) are *not* included in FHWA category of "highway law enforcement and safety." The other categories (hit-and run, DU I, other traffic crimes, and murder of police during traffic stops) require closer examination.

My reading of FHWA's *A Guide to Reporting Highway Statistics* (1990), and my conversations with FHWA officials, lead me to believe that most although perhaps not quite all crimes of hit and run are *not* covered by the FHWA category of highway law enforcement and safety. (In other words, the FHWA data might cover a very small fraction of hit and run crimes.) Conversely, it appears that few if any DUI crimes and "other traffic crimes" are *not* included in the FHWA data. (In other words, the FHWA data cover nearly all DUI crimes and "other traffic crimes.") I assume that only a small fraction of murders of police officers during a traffic pursuit or stop are not included in the FHWA data, on the presumption that most of the officers murdered were highway patrolmen.

My assumptions are shown in Table 7-10. These assumptions are consistent with my other assumption, in section 7.4.3, that 80% to 90% of the FHWA estimate of the cost of highway law enforcement and safety, or about $7 billion, is included in the Census estimate of total state and local police costs. Here's how: with the assumptions of Table 7-10, I calculate that 86% of all arrests by state and local police are *not* covered under the FHWA category of "highway law enforcement and safety," and hence that 14% *are*. Depending on what one assumes as the cost per arrest for the various crimes, this 14% corresponds to $3 to $7 billion of state and local police costs. In addition, state and local police have costs, perhaps of $1 to $2 billion, related to non-criminal traffic violations that don't result in arrests (the 14% figure is with respect to arrests). The resulting total of $4 to $9 billion is consistent with the $7 billion estimated independently in section 7.4.3.

7.4.7 Results of the analysis

Using both offense and arrest statistics, and estimating low and high for each, I have four different estimates of the motor-vehicle-related activity fraction, CFMV*, calculated thusly:

	Persons arrested		**Reported offenses**	
	Low	*High*	*Low*	*High*
Motor-vehicle-related, simple sum	3,132,992	3,132,992	4,742,190	4,742,190
Motor-vehicle-related, excluding FHWA estimates and substitute crimes (CMV*) (equation 7-18)	466,963	721,122	1,778,757	3,188,467
Total, excluding what is covered by FHWA (CT*) (equation 7-19)	12,088,277	12,088,277	14,972,657	14,972,657
Fraction of total that is related to MV use (excluding crimes for which there are substitutes) (CFMV*) (equation 7-17)	0.039	0.060	0.119	0.213

From these four I must pick a low-cost and a high-cost value. For my low-cost case, I use the lowest of the four CFMV* values, but for the high-cost case, I use the second-highest rather than the highest of the four CFMV* values, because the highest seems implausible to me. (These values are used in Table 7-2, and are assumed to apply to all analysis years, not just to 1991.) The vast majority of motor-vehicle related offenses (excepting DUI and other traffic crimes, which are included in the FHWA estimates of highway police and safety costs) are motor-vehicle theft or larceny theft (Table 7-10), and these crimes probably consume less police time and resources per incident than do violent crimes (which the police probably feel are more serious). It is possible even that theft crimes involving motor vehicles garner less police attention per incident than do other theft crimes, because they are so common yet so rarely cleared. If , therefore, the police cost per motor-vehicle offense is significantly less than the average police cost per any offense, then the motor-vehicle-related share of total police costs is less than the motor-vehicle-related share of offenses. For this reason, I do not use the estimated "high" motor-vehicle-related fraction of total offenses.

Nevertheless, there is a substantial difference between my low and my high estimate of the motor-vehicle-related fraction of total criminal activity. This wide range is due to two factors. First, the estimate based on arrests is much smaller than the estimate based on Crime-Index offenses, partly because relatively few crimes of motor-vehicle theft are cleared by arrest. Second, as discussed above, it is very difficult to determine what fraction of crimes that nominally involve motor vehicles would occur anyway even if there were no motor-vehicle use.

I believe, however, that the true opportunity cost of police protection related to motor-vehicle use lies between my high and low estimate. In any case, the total, including the police expenditures reported to FHWA, is nearly $10 billion. This is consistent with other evidence that police departments do in fact devote a lot of attention to motor-vehicle related activities. For example, virtually all police departments have primarily responsibility for traffic enforcement and accident investigation, and about 2/3 of state and local police departments operate special units that deal with drunken drivers (Bureau of Justice Statistics, *State and Local Police Departments, 1990*, 1992; *Sheriffs' Departments, 1990*, 1992).

7.4.8 Other costs of crime and police protection, estimated in other reports in the social-cost series

i) *The cost of preventing crime.* The cost of such things as anti-theft devices for cars is included in my estimate of the cost of goods and services produced and priced in the private sector (Report #5J). If such parts or services are formally classified as automotive merchandise by the Census' *Census of Retail Trade* (Bureau of the Census, 1995) or as automotive service according to the Standard Industrial Classification (SICs; Office of Management and Budget, 1987), then they are included in my estimates of expenditures for automotive merchandise or automotive services (SIC 75), in Report #5. Otherwise, I presume them to be included in the ad-hoc adjustment I make (also in Report #5) to account for expenditures on parts not formally classified as automotive merchandise or service by the Census.

One could argue that defensive expenditures on preventing crime should be classified separately as such, or perhaps even as external monetary costs, and not as costs of goods and services produced and priced in the private sector. I have not made this distinction here. (See Report #8 for a bit more discussion.)

ii) *Lost productivity, medical costs, and social-service costs due to motor-vehicle related crime.* Some motor-vehicle related crimes may injure people or make them less productive. These monetary costs of motor-vehicle-related crimes are estimated in Report #8.

To the extent that motor-vehicle goods, services, or infrastructure provide opportunities for crimes that would not be committed were there no motor-vehicle use, and thereby lure some people away from productive behavior, the lost productivity of motor-vehicle criminals, and the cost of incarcerations to the family of prisoners, arguably are costs of using or having motor-vehicle goods, services, or infrastructure. However, I do not estimate these costs here.

iii). *Pain, suffering, fear, anxiety, and avoidance behavior due to motor-vehicle related crimes.* These I classify as non-monetary externalities of motor-vehicle use (Report #9). I estimate the cost of the pain and suffering of the victims, but not the cost of the anxiety and avoidance.

The question of whether or not criminals would find substitutes for motor-vehicle-related crimes were there less motor-vehicle use and infrastructure is discussed in section 7.4.6 and in the notes to Table 7-10.

7.4.9 Overlap with emergency service costs of accidents

In Report #4, I estimate the cost of emergency police and fire services related to motor vehicle accidents. However, as discussed in that report, all of the police emergency service costs, and some of the fire-department emergency service costs, are included in the estimates of police costs and fire costs in this report. To avoid double counting, I have deducted from police and fire costs estimated here the emergency service costs that are included in both places. The deduction is shown in Table 7-23.

7.5 FIRE PROTECTION RELATED TO MOTOR-VEHICLE USE

7.5.1 Overview

Every year in the U.S. there are tens of thousands of motor-vehicle fires (U. S. Fire Administration, 1992). There also are fires at service stations, car dealerships, garages, and other places related to the use of motor vehicles. These motor-vehicle related fires cause hundreds of injuries and deaths, and millions of dollars in property loss (Table 7-12). Public fire departments devote considerable resources to fighting these fires.

Table 7-1 shows annual expenditures for fire protection in the U. S. The reported expenditures are for fire-fighting departments, auxiliary services, support of volunteer services, fire-hydrant charges, rescue squads, water and utility services used in support of fire-fighting, ambulances and paramedic squads and emergency medical technicians *if* they are handled by a fire department, and other fire-protection activities. They do not include expenditures related to forest fires.

In this section, I estimate the public-sector cost of fire-protection services related to motor-vehicle use. First, I estimate the annualized cost of all fire protection, using the method presented in section 7.1. Then, I estimate the shape of the total cost function (cost versus activity; in equations 7-8 and 7-14). Finally, I estimate the motor-vehicle related fraction of several cost-relevant measures of activity: fires, injuries, fatalities, and property loss. These last two steps are discussed below.

Note that there are also are non-monetary costs of fires related to motor-vehicle use: for example, pain and suffering due to injuries and deaths caused by motor-vehicle related fires. These are counted as non-monetary externalities, and included in Report #9.

7.5.2 The shape of the cost/activity function

Ideally, I would estimate the motor-vehicle cost of fire protection on the basis of the cost of fighting specific kinds of fires. However, there are no such cost data. Therefore, as mentioned above, I relate the cost of fire protection to several indicators: the number of fires, the number of injuries and fatalities from fires, and the value of property loss from fires. The National Fire Incident Reporting System (NFIRS; U. S. Fire Administration, 1992) reports data on fire incidents, injuries, fatalities, and property loss, by type of property involved in the fire.

The relationship between the number of fires and the cost of fire protection probably is similar to the relationship between the number of crimes and the cost of police protection, except that in the case of fire protection, a larger fraction of the total cost might be a "fixed" cost of maintaining minimum capacity, nearly independent of, or very insensitive to, the number of fires. This is because fires are rarer than crimes, to the point where firemen can be expected now to deal with *every* fire, whereas policeman of course cannot deal with all crimes. Put another way, fire departments might be sized and staffed primarily to handle infrequent large events, such that they might not be *much* different, in the long run, if there were fewer, say, motor-vehicle fires. By contrast, police departments probably are sized, in the long run, roughly in proportion to the total crime problem.

But, even in the case of fire services, there will be some savings if the frequency of relatively minor fires, such as motor-vehicle fires, is reduced. Certainly, one will save the operations cost, including wear and tear on equipment, of actually going to and putting out a fire. One will save on personnel training, because there now will be fewer fires to train for. And to the extent that fire-protection capacity is determined not on the basis of big, rare events (like block fires in residential areas) by themselves, but rather on the basis of rare big events *and* common minor events simultaneously (a block fire here and two motor-vehicle fires there), a reduction in the frequency of the minor events will reduce the necessary capacity.

These considerations suggest that cost/unit-activity decreases noticeably with increasing activity -- that is, that the exponent k in equations 7-8 and 7-14 is considerably less than 1.0. I assume 0.30 in the low-cost case, and 0.60 in the high-cost case.

7.5.3 The motor-vehicle share of cost-relevant activity: fires, injuries, deaths, and property loss

I use the property classification system of the NFIRS to estimate the motor-vehicle-related fraction of total fires, injuries, fatalities, and property loss. The NFIRS data are shown in Table 7-12. The U.S. Fire administration (USFA) gathers these data from the state fire administrations, which in turn get the data from local fire departments. According to staff at the USFA, about half of all fire incidents are not reported, but the distribution of unreported fires by cause and type of property damaged probably is similar to the distribution for reported fires. Therefore, I assume that statistics calculated from the NFIRS data are representative of all fires.

Table 7-12 shows the NFIRS data for every property class related to motor-vehicle use: garages, service stations, car dealerships, fuel storage, and "road property," which includes vehicle fires. The motor-vehicle share of fires, injuries, fatalities, or property loss is calculated simply as the ratio of motor-vehicle-related fires, injuries, fatalities, or property loss to all coded fires, injuries, fatalities, or property loss.

As shown in Table 7-12, motor-vehicle-related fires are relatively large fraction of total fires, but a much smaller fraction of total fire injuries, fatalities, and property loss. This seems reasonable, because most motor-vehicle-related fires are car fires, and car fires are not as dangerous or damaging as other fires. It therefore seems likely that the true motor-vehicle-fraction of total fire-protection costs is less than the motor-vehicle fraction of total fire incidents. I assume that at most 25% of the cost-relevant activity should be attributable to motor-vehicle use. As a lower bound, I use the motor-vehicle-related fraction of total fire property loss, which is about 15%. (These values are used in Table 7-2, and are assumed to apply to all analysis years, not just to 1991.)

If these percentages are used to allocate the total fire expenditure in the United States, then something on the order of $1 to $2 billion was spent fighting fires that were related to motor-vehicle use. Informal discussions with industry experts confirmed that this range of costs seemed like a reasonable approximation.

Technically, motor-vehicle related arson should be analyzed separately, because, being a crime, it often will be a cost not of motor-vehicle use per se, but rather of criminal behavior in general. However, I assume that a separate treatment of arson would not significantly change the results presented here.

Estimating costs for individual classes of motor-vehicles. Table 7-13 shows NFIRS data by type of motor-vehicle involved. These data, along with the data of Table 7-12, can be used to allocated costs to individual vehicle types.

7.6 COURT COSTS RELATED TO MOTOR-VEHICLE USE

7.6.1 Overview

In Table, in 1991, federal, state, and local government spent about $20 billion on their court systems (Table 7-1). Cases involving motor vehicles account for a significant fraction of this total.

The method used here to estimate court costs related to motor-vehicle use is similar to the method used above for police-protection and fire-protection costs. First, I estimate the annualized cost of the federal, state, and local judicial system, on the basis of the expenditure data of Table 7-1. To derive annualized capital and annual operating maintenance costs from expenditures, I use the method presented in section 7.1. Then, I disaggregate the costs, at each level of government, into costs for different case subareas (personal injury, auto theft, tort, etc.; see Table 7-14), on the basis of the amount of time per case and the number of cases in each sub area. Finally, I estimate the motor-vehicle share of each kind of case.

The data and results are presented in Tables 7-2 and 7-14.The most important step -- the allocation of total costs to different case areas, on the basis of time (time/case multiplied by the number of cases) devoted to each case area -- is discussed in some detail below. But before turning to that, I discuss briefly the shape of the cost/activity function for the court system.

7.6.2 The shape of the total cost function

I assume that expenditures on the judicial and legal system are a function of the total amount of time spent on cases. The total case time can be estimated as the product of the time per case and the number of cases, in each case subarea (auto theft, other felonies misdemeanors, DUI, juvenile offenses, traffic violations, civil cases, and so on-- see Table 7-14).

It seems likely that, in the long run, virtually all of the costs of the judicial system are proportional to the judicial caseload and the time per case. Judges and lawyers work on specific cases; the fewer the cases, the less work. If there is a permanent reduction in the number of cases of a particular type, or a reduction in the average time per case, then either there will be a corresponding reduction in the amount of judicial resources devoted to cases in the long run, or else a better job done on the remaining cases. (Most likely, it will be a combination of the two effects.) Either way, society gains, either by devoting fewer resources to the same amount of justice, or getting more justice for the same amount of resources, and hence either way some of the resources of the justice system are a long-run marginal cost of motor-vehicle use.

If the cost/case-time function is indeed nearly linear, then the exponent k in equations 7-8 and 7-14 is very close to 1.00. My assumptions are shown in Table 7-2

7.6.3 Estimating the costs of the judicial system, on the basis of time spent adjudicating different cases

In 1990 there were over 100 million filings in Federal and state court, not including cases heard before appellate courts, state supreme courts, or the U.S. supreme court (Court Statistics Project, 1992). Nearly 99% of the filings were in state courts, and most of the filings in state court were related to traffic offenses or DUI (Court Statistics Project, 1992). Thus, the motor-vehicle-share of total cases is relatively large, and if costs were related only to the number of cases, and not also to the time per case, then the motor-vehicle share of total costs would be relatively large too. However, the vast majority of motor-vehicle-related cases are traffic offenses or DUI, and I believe that traffic offenses certainly, and DUI cases probably, take up much less court time than do most other cases. Therefore, as mentioned above, I relate costs not to just the number of cases (case filings, actually), but rather to the total time (which is the product of cases and time per case), and estimate the motor-vehicle-related share of total case-time rather than of total cases.

As shown in Table 7-14, I break out the judicial caseload into several categories, and for each category estimate the percentage of cases that are related to motor-vehicle use. I also estimate the amount of time spent on each type of case, relative to the time spent on traffic offenses (which are given a weight of 1.0). (I have normalized the reported time/filing in each case area to the time required for traffic cases because only the relative time per case matters here.) The estimates of the normalized time per case are based on actual data on minutes spent per filing in California municipal courts in 1986. These data are shown in Table 7-15. With these two assumptions (the motor-vehicle share of cases, and the relative time per case, in each subarea), I can estimate the motor-vehicle share of total case time[16].

Because it is not clear precisely what is included in the "traffic" cases reported by the Court Statistics Project (1992) and shown in Table 7-14 (see notes to that table), I have normalized with respect to two different definitions of "traffic" cases: one that includes all traffic misdemeanors and infractions but excludes parking cases, and another that includes parking cases. Because parking cases take so little time, times normalized with respect to traffic-with-parking are much higher than times normalized with respect to traffic-without-parking.

Table 7-14 does not include cases heard in U.S. District Courts, appellate courts, or supreme courts. I believe, though, that motor-vehicle related expenditures for these courts are quite small. Filings in U.S. District courts constitute only 1% of total filings in Federal and state courts. Half of these filings are for bankruptcy, and 92% of the bankruptcy cases are non-business (Court Statistics Project, 1992). I expect therefore that the absolute number of motor-vehicle related filings in U.S. District Courts is tiny. Similarly, lawyers and general news articles tell me that very few of the cases heard before appellate courts and supreme courts involve motor vehicles. And since there is no reason to believe that motor-vehicle related cases consume a disproportionate amount of time per case, total motor-vehicle related expenditures in U.S. District Courts, appellate courts, and supreme courts must be quite small.

The estimates of Table 7-14 also do not include motor-vehicle related costs associated with out-of-court settlements or private legal assistance (not covered by automobile insurance). I am unable to estimate these.

Finally, note that this method leaves unaccounted the cost of handling parking violations outside of the court system.

The estimates of Table 7-14 are used to estimate the motor-vehicle shares of Table 7-2. The resultant values are assumed to apply to all analysis years, not just to 1991.)

7.7 PRISON, PROBATION, AND PAROLE COSTS RELATED TO MOTOR-VEHICLE USE

7.7.1 Overview

[16]Ideally, I would weight filings not by relative time-use per filing, but by relative resource-use per filing. However, I assume that the cost of time (wages) is a large part of total expenditures, and that resource-use weights would be very similar to time-use weights.

A significant percentage of the people under correctional supervision have been convicted of crimes related directly or indirectly to motor-vehicle use: driving under the influence (DUI), theft of motor vehicles, robbery of service stations, theft from motor vehicles, arson to motor vehicles, hit and run, and other traffic offenses. Many of the inmates who have committed crimes related directly or indirectly to motor-vehicle use would not be in prison were there no motor-vehicle use. In the long-run, this reduction in the number of inmates would result in a reduction in the costs of prisons, jails, probation, parole, and correctional administration.

In this section, I estimate the motor-vehicle-related fraction of the total cost of corrections, on the basis of the motor-vehicle related fraction of total inmates and parolees. The method is similar to that for police, fire, and judicial-system costs. First, I estimate the total annualized costs of the federal, state, and local correctional system, on the basis of the expenditure data of Table 7-1. To derive annualized capital and annual operating and maintenance costs from expenditures, I use the method presented in section 7.1. Then, I disaggregate the costs, at each level of government, into three subareas: institutions (prisons or jails), PP&P (probation, parole, and pardons), and other correctional activities (mainly administration). Finally, I estimate the fraction of the prison, jail, or parole population whose primary offense was related to motor-vehicle use.

The data and results are presented in Table 7-16. The results of Table 7-16 are used to estimate the motor-vehicle fractions of Table 7-2 and are assumed to apply to all analysis years, not just to 1991. The most important data -- the motor-vehicle-related shares of offenses in each sub-area -- are discussed more below.

7.7.2 The shape of the total-cost function

I assume that in the long run, essentially all of the costs of the correctional system scale with the number of prisoner-days. With regards to the general discussion in section 7.1.2, I assume specifically that in the long run, prison capacity is proportional to the number of prisoner-days. This seems reasonable: cells house inmates, guards guard inmates, and parole supervisors supervise ex-inmates. If there is a permanent reduction in the number of inmates of a particular type, then either there will be a corresponding reduction in the amount of correctional resources devoted to inmates in the long run, or else a better job done with the remaining inmates (most likely, a combination of the two effects). Either way, society gains, either by devoting fewer resources to corrections, or getting more correctional service, and hence either way some of the resources of the corrections system are a long-run marginal cost of motor-vehicle use.

For these reasons, I assume that the exponent k in equations 7-8 and 7-14 is very close to 1.00.

7.7.3 The fraction of the jail or prison population convicted of motor-vehicle related crimes

Table 7-17 shows inmates in jails, state prisons, and federal prisons, by type of offense. The objective of this table is to estimate the fraction of inmates (in each kind of institution -- jail, state prison, or federal prison) that would not be in jail or prison were there no motor-vehicle use. The overall fractions, shown at the bottom of the Table 7-17, are estimated as follows:

$$IFMV = \frac{\sum_{C^\wedge} JPI_{C^\wedge} \cdot CFMV_{C^\wedge}}{\sum_{C^\wedge} JPI_{C^\wedge}} \qquad \textbf{[7-20]}$$

where:

IFMV = of total prison or jail inmates, the fraction that would not be incarcerated were there no motor-vehicle use
$JPI_{C^\wedge}$ = jail or prison inmates convicted of crime C^ (Table 7-17)
$CFMV_{C^\wedge}$ = the motor-vehicle-related fraction of crime C^ (Table 7-17; equation 7-21).
subscript c^ = general crime categories (homicide, robbery, etc.; Table 7-17)

The motor-vehicle related fraction. The motor-vehicle-related fraction of crimes can be understood to be the fraction by which crimes in each general category (homicide, robbery, etc.) would be reduced, on balance, were motor-vehicle use eliminated. For the crimes categories (C^, Table 7-17) of kidnapping, assault, other violent crimes, burglary, stolen property, other stolen property, drug offenses, and public-order offenses except traffic and DUI, this fraction is assumed to be zero. In other words, I assume that changes in motor-vehicle use would not affect these kinds of crimes. For the other crime categories, the motor-vehicle-related fraction is estimated as:

$$CFMV_{C^\wedge} = \frac{\sum_{C \in C^\wedge} CMV_{C \in C^\wedge} \cdot S_{C \in C^\wedge}}{CT_{C^\wedge}} \qquad \textbf{[7-21]}$$

where:

$CMV_{C \in C^\wedge}$ = Number of crimes (offenses or arrests) of type C, nominally related to motor-vehicle use, in the general crime category C^ (Table 7-10)
$S_{C \in C^\wedge}$ = of motor-vehicle-related crimes C in general crime category C^, the fraction for which there are no substitutes (Table 7-10, and section 7.4.6)
$CT_{C^\wedge}$ = the total number of crimes (offenses or arrests) in general crime category C^ (Table 7-11)

subscript c = specific crimes nominally related to motor-vehicle use (e.g., robbery of a gas station; see Table 7-10, and brief discussion below)

subscript $c \in C^\wedge$ = specific crimes, nominally related to motor-vehicle use, in general crime category C'; for example, robbery of gas stations is a specific crime, nominally related to motor-vehicle use, in the general crime category "robbery"

An offense is "nominally" related to motor-vehicle use if it in some way involves motor-vehicles, or motor-fuels, or the motor-vehicle infrastructure. Thus, motor-vehicle theft is nominally related to motor-vehicle use. However, motor-vehicle thieves, whose crimes nominally are related to motor-vehicle use, might still end up in prison even if there were no motor vehicles to steal, because they might steal something else. The "substitution" factor, S in equation 7-21, accounts for these effects: it is an estimate of the fraction, of total motor-vehicle-related crimes, for which there are no substitutes. (See section 7.4.6 for further discussion.) Note that for some nominally related crimes, such as hit and run and especially DUI, there are no plausible substitutes.

7.7.4 The fraction of the probation, parole, and pardon (PP&P) population convicted of motor-vehicle related crimes

The method for estimating the fraction of the PP&P population convicted of motor-vehicle related crimes is the same as the method, outlined in section 7.7.3, for estimating the motor-vehicle-related fraction of prison and jail inmates:

$$Assume:\ PPPFMV = PFMV$$

[7-22]

$$PFMV = \frac{\sum_{C^\wedge} PM_{C^\wedge} \cdot CFMV_{C^\wedge}}{\sum_{C^\wedge} PM_{C^\wedge}}$$

where:

PPPFMV = of the total probation, parole, and pardon (PP&P) population, the fraction that would not exist were there no motor-vehicle use

PFMV = of the total parole population, the fraction that would not exist were there no motor-vehicle use

$PM_{C^\wedge}$ = man-months of parole served by offenders of type C^ (Table 7-18)

$CFMV_{C^\wedge}$ = the motor-vehicle-related fraction of crime C^ (Table 7-17; see discussion in section 7.7.3)

The data and results are shown in Table 7-18. Note that the fractions are estimated with respect to parolees only, whereas ideally I should use fractions based on probation and pardons as well. However, there are no data on pardons by offense, and in any case there must be but few pardons, of little total cost. Although there are data on persons on probation by type of offense, the data are cumbersome. Because the cost of PP&P is much smaller than the cost of jails and prisons, and because parole supervision probably is the most costly function in the PP&P category, it is satisfactory to allocate all PP&P costs on the basis of the offenses of the parole population.

7.7.5 Allocation of "other" corrections expenditures

I do not know enough about the costs in this category to be able to relate them to motor-vehicle use. Therefore, I assume that the percentage of "other" corrections costs that should be attributed to motor-vehicle use is equal to the percentage I calculate for institutions, and probation, pardon and parole combined.

7.8 REGULATION AND CONTROL OF AIR POLLUTION, WATER POLLUTION, AND SOLID WASTE

7.8.1 Overview

In 1991, state, local, and federal government agencies in the U. S. spent nearly $40 billion dollars to abate and regulate pollution (Bureau of Economic Analysis [BEA; Vogan, 1996]; Table 7-19). The bulk of this was to build and operate public sewers (about $24 billion) or operate solid waste facilities (about $11 billion). About $2 billion was spent on regulation, and less than $1 billion was spent on research and development (Table 7-19). (Private industry spent tens of billions more on pollution abatement[17], but in my analysis, all of this is counted as a private-sector cost.)

In this section, I estimate the public-sector cost of pollution abatement and regulation related to motor-vehicle use. First, I use the method presented in section 7.1.2 to derive annualized capital and O&M costs from the BEA data on public expenditures for the regulation and abatement of pollution. The BEA expenditure data are shown in Table 7-19, and the annualization parameters are shown in Table 7-2. Then, I estimate the shape of the total cost function (cost versus activity; in equations 7-8 and 7-14). Finally, I estimate the motor-vehicle-related fraction of the cost-relevant measures of activity (pollution, in this case). The last two steps are discussed below.

I assume that in each expenditure sub-area (i.e., each cell in Table 7-19), the total annualized cost is some function of the amount of pollution being abated or regulated.

7.8.2 The shape of the total-cost function

In the categories of air pollution and other pollution (noise, radiation and pesticides) in Table 7-19, virtually all government expenditures are for regulation and monitoring, research and development, and "other" federal and state abatement

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[17]For example, the BEA estimates that in 1991 businesses spent $5.8 billion on air-pollution-abatement for motor vehicles (Vogan, 1996). This comes to $600-$700 per vehicle, which seems reasonable.

activities. It seems likely that in the long run, these expenditures are roughly proportional to the quantity of pollution being regulated or abated. Thus, for air and other pollution, I assume that k = 1.0.

Virtually all solid-waste costs are state and local expenditures for waste collection and disposal. Collection and disposal costs presumably are proportional to the mass and volume of material collected. If so, then it also is reasonable to assume that in the case of solid waste, k = 1.0.

The case of water pollution is trickier. Nearly all of the expenditures in this category are for building and operating public sewer systems. Now, certain operating costs probably are proportional, in the long run, to the pollutant load at sewer systems. However, it is unlikely that the capital costs of sewer systems are proportional to the anticipated pollutant load. For example, if sewer systems are sized and designed to handle infrequent "large" loadings, then the capital outlay will be virtually independent of the average expected loading. For this reason and others, I expect that a system with half the pollutant load (however defined) of another will cost much more than half as much as the other. I therefore assume that the long-run marginal cost of public sewer systems decreases quickly with capacity, and that k is considerably less than 1.0.

7.8.3 The motor-vehicle fraction of air, water, and solid-waste pollution regulated and controlled by government

I have assumed that the long-run regulatory or abatement cost attributable to motor-vehicle use, as a fraction of the total regulatory or abatement cost, is some function of the motor-vehicle-related fraction of the amount of pollution regulated or controlled. In this section, I estimate the motor-vehicle-related fraction of pollution in each cell of Table 7-19.

In general one faces two difficulties here. The first is to determine which measures of pollution are most closely associated with the cost of regulation and control. This is difficult because there are many kinds of pollutants, with different kinds of effects and control requirements, and different motor-vehicle-related fractions. The second is to determine the motor-vehicle-related contribution to the ambient pollutant levels or burdens that actually are regulated or controlled, as opposed to the motor-vehicle-related contribution to source emissions.

In the following paragraphs, I explain the motor-vehicle activity fractions in the most important expenditure areas: public sewers, air pollution, and refuse collection and landfilling. The other activity fractions are explained briefly in the notes to Table 7-19.

Public sewers: all pollution categories. The first task here is to make sure that I do not count in this section any motor-vehicle-related expenditures already counted in other sections of this report. (For example, expenditures on highway storm drains might be included here under "public sewer expenditures" as well as under "highway expenditures".) This requires a determination of the functions included in the "public sewer" expenditure category of the BEA.

The BEA does not describe its "public sewer" expenditure category. However, the Bureau of the Census does describe a "sewerage" expenditure category (for its *Government Finance* series), and this "sewerage" category appears to be the same as the BEA's "public sewer" expenditure category: the BEA gets its data on public-sewer expenditures from the Census (Vogan, 1996), and as a result, both sources report about the same expenditures. The Census' *Classification Manual* (1992) describes what is included in the Census' "sewerage" category:

> Construction and maintenance of sanitary sewer lines; sewer cleaning; lift or pump stations; sewage treatment plants; water pollution control plants; storm drains that are not connected with highway projects; systems for the collection and disposal of storm runoff; and any intergovernmental payments for such activities (80-0).

Note that storm drains associated with highway projects (apparently included already in the FHWA's estimates of expenditures for highways -- see notes to Table 7-3) are explicitly excluded here. Thus, on the basis of the Census' description, I assume that the "public sewer" expenditure category does not include any costs already counted elsewhere.

The next task is to identify the general sources of water pollution related to the use of motor-vehicles, and determine which sources might affect public sewers. There are several sources of water pollution related to the use of motor-vehicles:

i) erosion from highway construction
ii) large spills and leaks from crude oil extraction, storage, and transport
iii) discharges from refineries and motor-vehicle manufacturing plants
iv) spills and leaks from fuel transport and storage
v) oil, grease, fuel, and other motor-vehicle chemicals in urban runoff or improperly disposed in sewer systems

Erosion from highway construction (item i) is counted as a separate category in Table 7-19. Large oil spills (item ii), as considered apart from oil in urban runoff, probably do not affect sewer systems. (Certainly, large marine spills do not.) Large industrial point sources (item iii) presumably treat their waste themselves, and then discharge the treated effluent into rivers, lakes, or bays, not sewer systems. And leaks from underground storage tanks (item iv) threaten groundwater, not sewer systems. That leaves, for this section of the analysis, item v, urban runoff.

There is no question that oil and grease is a substantial part of the pollution in sewer systems, and that motor-vehicle use is responsible for most of the oil and grease pollution. In Report #9, we cite recent research that shows that motor vehicles are a major source of pollution in urban runoff. Also, informal conversations with engineers with the city of San Francisco indicate that about 10-20 percent of the pollutants in the city sewer system are oil and grease. At least half of this could be attributed to motor-vehicle use. Of course, oil and grease may be more or less costly to deal with than the average pollutant, and ideally one would account for this difference. However, I simply assume that all pollutants are equally costly to handle.

Thus, on the basis of the foregoing, I assume that 5-10% of the pollution handled by sewer systems can be attributed to motor-vehicle use.

Federal, state, and local expenditures on regulation, R &D, and other pollution abatement and control: air pollution. Governments regulate and control a wide range of air pollutants: ozone (O_3), carbon monoxide (CO), nitrogen oxides (NO_X), volatile organic compounds (VOCs), sulfur oxides (SO_X), particulate matter (PM), lead (Pb), toxic air pollutants (including benzene and formaldehyde), and others. Ozone air pollution and its precursor emissions, NO_X and VOCs, probably consume the bulk of government air-pollution regulatory and control resources, with regional acid pollutants and their precursors, NO_X and SO_X, second.

I assume that air pollution regulatory and control expenditures are related to an aggregation of the individual ambient pollutants weighted according to the regulatory effort devoted to each pollutant. The motor-vehicle share of this effort-weighted aggregate pollution measure is equal to the motor-vehicle contribution to each ambient pollutant, multiplied by the relative regulatory effort devoted to the pollutant, summed over all pollutants:

$$APFMV = \sum_{AP} MVF_{AP} \cdot RE_{AP} \qquad \textbf{[7-23]}$$

where:

subscript AP = the ambient pollutants regulated (VOCs [as a proxy for ozone], CO, NO_X, SO_X, and PM)

APFMV = the motor-vehicle-share of the cost relevant (effort-weighted) measure of air pollution

MVF_{AP} = the motor-vehicle contribution to ambient pollutant AP (discussed below)

RE_{AP} = the relative regulatory effort devoted to ambient pollutant AP; I assume the following:

CO	NOx	VOC	SOx	PM-10
0.10	0.20	0.35	0.20	0.15

The motor-vehicle contribution to ambient pollution (MVF_{AP}) can be estimated on the basis of the EPA's official estimates of the pollutant emissions from motor vehicles, with adjustments for errors in the EPA emission estimates, the additional contribution of "upstream" motor-vehicle related emissions, and the relationship between emissions and ambient pollution. The EPA estimates, and my adjustments, are discussed next.

The EPA estimates national emissions of CO, NO_X, VOCs, SO_X, and PM from motor-vehicles and all other sources (EPA, 1996). With these data, one can calculate that motor-vehicles directly accounted for the following shares of emissions in 1990:

CO	NOx	VOC	SOx	PM-10
0.62	0.33	0.29	0.03	0.01

However, the EPA likely underestimates motor-vehicle emissions of all pollutants except SO_X, and overestimates emissions of dust (see Report #16). Correcting the emission estimates would increase the motor-vehicle shares shown above. Furthermore, some portion of emissions in other categories in the EPA inventory, such as petroleum refining and road dust, should be assigned to motor-vehicle use. Adding these upstream emissions would increase the VOC and NO_X shares by about 33% (relative terms), the SOx shares by several fold, and the PM share by at least a factor of 20 (because of road dust) (Report #10; Report #16; DeLuchi et al., 1992; Delucchi, 1998). Finally, one must consider that a gram emitted from a motor vehicle on average contributes more to the ambient urban air pollution that is the focus of the regulation than does a gram emitted from, say, a power plant, mainly because motor vehicles are closer to urban centers than are large point sources (Report #16).

Considering all these corrections and adjustments, I estimate that motor-vehicles and related sources (refineries making gasoline, road dust, and so on) contributed the following to total urban ambient air pollution (MVF_{AP} in equation 7-23):

CO	NOx	VOC	SOx	PM-10
0.80	0.60	0.60	0.20	0.40

Plugging these values into equation 7-23, along with the assumptions above regarding RE_{AP} , I calculate that APFMV, the motor-vehicle share of the cost-relevant measure of air pollution, is 50%. On this basis, I assume a range of 40% to 60% in Table 7-19.

Other state and local operating and maintenance expenditures on pollution abatement and control: solid waste. The first task here is to make sure that I do not count in this section any motor-vehicle-related expenditures already counted in other sections of this report. (For example, expenditures on street cleaning might be included here under "solid waste expenditures" as well as under "highway expenditures".) This requires a determination of the functions included in the "solid waste" expenditure category of the BEA.

The BEA does not describe its "solid waste" expenditure category. However, the Bureau of the Census does describe a "solid waste" expenditure category (for its *Government Finance* series), and this category appears to be the same as the BEA's expenditure category of the same name: the BEA gets its data on solid-waste expenditures from the Census (Vogan, 1996), and as a result, both sources report about the same expenditures. The Census' *Classification Manual* (1992) describes what is included in the "solid waste" category:

> Garbage collection; sanitary landfills; hazardous waste disposal sites; incinerators; pyrolysis facilities; clean up of toxic chemical spills and dumps; collection and disposal of abandoned vehicles; resource recovery authorities, including those which cogenerate electricity or gas as a by-product; recycling centers; Federal "Superfund" activities; cleaning and washing of streets; and collection and disposal of street debris and trash (81-0).

Note that collection and disposal of abandoned vehicles, and cleaning and washing of streets are explicitly included -- and obviously related to motor-vehicle use. However, the cost of street cleaning, and the cost of removing motor-vehicle junk, presumably are included already in the FHWA estimates of maintenance and repair expenditures for highways (Table 7-3 here): FHWA's *A Guide to Reporting Highway Statistics* (1990) states that "miscellaneous expenditures" include "expenditures for activities (such as control of outdoor advertising and junkyard removal) associated with beautification" (p. 8-10). (Note too that snow and ice removal is explicitly excluded from the Census' "solid waste" expenditure category, but included in the FHWA estimates of maintenance expenditures.)

What is left for this section of the analysis, then, are the following sorts of activities:

i) clean up of hazardous chemicals and materials related to motor-vehicle use[18]
ii) management of hazardous-waste disposal sites and incinerators that deal with chemicals and materials related to motor-vehicle use
iii) collection and disposal of motor-vehicle parts and equipment that are thrown out with the collected trash, rather than abandoned along the highway
iv) management of landfills and disposal sites with motor vehicles and motor-vehicle parts and equipment (unless this is covered in the cost of "junkyard removal" included in the FHWA estimates)[19]

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[18]In Report #9, we estimate the external cost of oil spills and leaking underground storage tanks, and exclude from our estimates government clean up costs that theoretically should be included in this section.

[19]Note that any environmental damages from motor-vehicle refuse should be accounted separately. I classify but do not estimate such damages in Report #9 of this social-cost series.

It is not easy to estimate the motor-vehicle share of these activities. I suspect, though, that the motor-vehicle-related share of all of the solid-waste management activities (excluding street cleaning and disposal of abandoned vehicles) is relatively small. Most motor-vehicles, major motor-vehicle parts, and motor-oil are recycled. Presumably, public authorities deal with only a small fraction of the total motor-vehicle waste stream[20]. I can't imagine that more than 10% of solid-waste-management activities involve motor vehicles, motor-vehicle parts, motor fuels, or motor oil. I assume a range of 4-8%.

7.8.4 Results of the analysis

With the expenditure data in part A of Table 7-19, the motor-vehicle activity shares in part B, and the other cost parameters shown in Table 7-2, the motor-vehicle-related costs of pollution regulation and control, in each pollution regulation and control sub-area, are calculated using equations 7-7 and 7-13f. The results are shown in part C of Table 7-19. Note that the motor-vehicle activity shares in Table 7-19 are assumed to apply to all analysis years, not just to 1991.

7.8.5 User charges for regulatory activities

A small portion of the agency expenditures for regulation and control are covered by taxes or charges on users. For example, in 1993 Walsh (1993) reported that the EPA had finalized rules establishing a program under which the agency collects fees from motor vehicle manufacturers to cover the cost of its Motor Vehicle and Engine Compliance Program, which includes emissions certification, fuel-economy testing, in-use compliance testing, auditing, and enforcement (Walsh, 1993). Thus, some portion of the EPA's regulatory costs are embedded in the cost of a motor vehicle. Similarly, the Oil Pollution Act of 1990, implemented by the EPA and the Coast Guard, established a trust fund of $1 billion, financed by a 5-cent-per-barrel fee on domestic and imported oil (Council on Environmental Quality, 1992). Thus, part of the federal costs that will be incurred in the cleaning up of oil spills will have been paid for, in advance, by the use of oil. And finally, at least some of whatever public authorities do spend on disposing of motor-vehicle junk is covered by revenues from the "abandoned vehicle fee" that is collected with motor- vehicle registration in some states (e.g., $1/vehicle/year in

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[20]Lee (1995) suggests that public authorities might pay upwards of $500 million per year to dispose of motor vehicles, but I doubt that the amount is this high. In the first place, the private sector handles most scrappage, and most motor-vehicles are recycled. (For example, a sample survey of about 600 last owners of cars scrapped in 1987 in the Netherlands found that 52% of the cars were sold to a scrap yard, 29% were sold to a garage, 5% were sold privately, 2% were stolen, and 12% had "other" destinations [Ghering et al., 1989].) The public sector probably handles much less than 10% of the scrappage, or well under a million vehicles per year. Second, it probably costs public authorities no more than $50 to $100 to scrap a vehicle. This suggests a total cost an order of magnitude lower than $500 million.

California). There may be other charges for government regulatory and abatement costs.

The costs covered by user charges such as these can be classified in at least three ways: as private costs, as government costs, or as costs covered by government charges. I classify them here as government costs, and then count the corresponding user charges as user payment for motor-vehicle-related government goods and services, in Report #17.

7.8.6 Updating costs for years other than 1991.

To estimate motor-vehicle-related pollution control costs for any year Y, we multiply estimated expenditures on pollution control in year Y by the motor-vehicle-related fraction of the expenditure, in each pollution-control-expenditure category. Table 7-19A shows total expenditures on pollution control, by government level and expenditure category, in 1991. Table 7-19B shows the motor-vehicle-related fractions in each expenditure category, in 1991. I assume that the Table 7-19B fractions, estimated on the basis of 1991 data, apply to any year Y. Thus, the remaining task is to estimate total pollution control expenditures, in the categories of Table 7-19, for any year Y other than 1991.

To estimate pollution control expenditures, by expenditure category, in years other than 1991, we multiplied the actual 1991 expenditures in each category (Table 7-19A) by an estimated annual rate of change factor:

$$PCC_{Y,E} = PCC_{1991,E} \cdot \left(PCF_E\right)^{Y-1991}$$

where:

subscript E = expenditure categories (the cells of Table 7-19A; e.g., abatement and control costs of publically owned electric utilities for water pollution)

Y = year of interest

$PCC_{Y,E}$ = the motor-vehicle-related pollution-control expenditure category E in year Y ($)

$PCC_{1991,E}$ = the motor-vehicle-related pollution-control in expenditure category E in 1991 (Table 7-19A)

PCF_E = the annual rate of change in the motor-vehicle-related pollution-control expenditure in category E (1+%change; discussed below)

To estimate the annual rate of change factor in each expenditure category (PCF_E), we first calculated the actual annual change rate in each expenditure category from 1991 to 1994. (To do this, we used the BEA data from Vogan [1996] to produce Table 7-19A for the year 1994, the last year for which the BEA ever estimated pollution abatement and control expenditures. After Vogan's 1996 article, the BEA stopped estimating these expenditures.) We also examined qualitatively the longer historical trends evident from the 1972 to 1994 data in Vogan (1996). Considering the calculated 1991/1994 annual percentage changes and the longer term trends, we made assumptions for the annual change factors PCF_E.

7.9 RESEARCH AND DEVELOPMENT OF MOTOR-VEHICLES AND MOTOR FUELS

In this section, I estimate public expenditures for research and development of motor-vehicles and motor-fuels. Because the expenditures appear to be relatively small, and in some cases the data are poor, I simply estimate the total annual cost directly, rather than estimate the individual parameters of the detailed cost equation 7-14.

7.9.1 Motor-vehicle-related expenditures by the U. S. Department of Energy

The federal government and the states support research and development (R & D) of energy feedstocks, energy conversion processes, and energy end-use technologies related to highway transportation. The government sponsors these projects because most of them are too risky, uncertain, long-range, or unprofitable (e.g., research on clean-burning fuels) for private industry[21].

DeLuchi et al. (1987) used the work of Cone et al. (1980) and Heede et al. (1985) to estimate that federal-agency expenditures related to oil use amounted to approximately $1 to $2 billion (1985 $). Approximately half of this could be assigned to motor-vehicle use. Note that these do not include what sometimes are referred to as "tax expenditures," which are estimates of foregone government revenues, not estimates of economic costs. (See Report #18 in this social-cost series for estimates of tax expenditures.)

More recently, the EIA (*Federal Energy Subsidies*, 1992) has estimated federal appropriations for energy R & D. Table 7-20 lists the appropriations that directly or indirectly relate to highway transportation, and the portion of the appropriations, in each category, that should be assigned to motor-vehicle use. The data of that table indicate that in fiscal year 1991, about $100 million was appropriated for R & D on highway fuels, and another $100 million was appropriated for R & D on transportation end-use technologies (such as electric vehicles). However, the EIA (*Federal Energy Subsidies*, 1992) states, but does not show, that appropriations for all programs that provide liquid transportation fuels amounted to $300 million in fiscal year 1992 (p. 45). This would seem to imply that there are additional energy R & D expenditures related to transportation not included in Table 7-20, or else that the motor-vehicle shares of Table 7-20 are too low. I assume a range of $100 to $300 million on energy R & D on transportation fuels.

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[21]Note that whether or not government R & D expenditures related to highway transportation make sense economically is a separate question from whether or not the expenditures are a social cost of motor-vehicle use. The government might not spend money wisely, but whatever it spends on highway transportation is, *ipso facto*, a cost of highway transportation.

Note that the EIA estimates *federal* appropriations for *energy* R & D only; it does not estimate state appropriations for energy R & D, or appropriations by environmental or transportation agencies.

7.9.2 Motor-vehicle-related expenditures by state energy offices

There is no compilation of the budgets of all state energy offices, let alone a compilation of motor-vehicle-related expenditures by state energy offices. As a crude estimate of the undoubtedly minor motor-vehicle-related R&D expenditures by state energy offices, I estimated expenditures in New York and California, and then extrapolate to all 50 states.

In fiscal year 1991-1992, the alternative-fuel-vehicle program of the New York State Energy Research and Development Authority (ERDA) received $4.9 million -- $2.0 million dollars from the Energy Authority (mostly money from the Petroleum Overcharge Restitution Fund [PORF], funneled through the New York State Energy Office), and $2.9 million from outside matching sources (Bass, 1993). ERDA's total budget was $60 million. The New York State Energy Office did not spend any significant monies on programs related to motor-vehicle use.

The California Energy Commission (CEC) spent $47 million total in fiscal year 1991 (California State Controller ,1992). I estimate that 20% of the expenditures, or about $10 million, were related to motor-vehicle use.

If all states spent money on motor-vehicle energy R&D in proportion to VMT in the state, then the data from New York and California suggest that all state energy offices spend nearly $100 million per year on R & D on motor fuels or motor vehicles. I assume a range of $50 to $100 million.

As mentioned above, the national PORF, which consists of fines levied on oil companies for putative price gouging in the 1970s, funds some state energy offices. Ironically, the fines probably are treated as an extra cost of doing business and passed on to consumers in the form of higher prices. In fact, it probably is reasonable to assume that the fines in effect are government taxes, and that the total amount of the fines is covered by additional price-times-quantity payments by consumers. This means that, in principle, I should estimate PORF-related costs passed on to motor-vehicle users and count them as payments by motor-vehicle users for motor-vehicle use. I do this in Report #17.

7.9.3 Motor-vehicle related research and development expenditures of other government agencies

The U. S. Department of Transportation (DOT) and state transportation departments fund research related to motor-vehicles and motor-vehicle infrastructure. (For example, the Federal Highway Administration of the U.S. DOT supported this social-cost research.) However, all such expenditures are supposed to be included in the "Administration and Research" category of FHWA's *Highway Statistics* (Table 7-3 here). According to *A Guide to Reporting Highway Statistics* (FHWA, 1990), highway planning and research includes "all expenditures for research and investigation, including laboratory and field research inroad and bridge materials and design, traffic research, financial studies, and similar investigations by the state highway planning division or similar agencies" (p. 8-10). Therefore, I assume that all relevant energy and technology expenditures by DOTs are included in Table 7-3.

Air-quality agencies, such as the California Air Resources Board, also fund energy and technology R & D of motor vehicles and motor fuels. However, I presume that these expenditures are included in BEA's estimates, discussed above, of state and federal R & D expenditures for pollution abatement and control. (Conversely, I also assume that the BEA estimates do not include expenditures by state or federal energy agencies.)

The Department of Commerce also funds some vehicle technology programs. I ignore these.

7.9.4 Total motor-vehicle-related R&D expenditures by government energy offices

I estimate that in 1991 all government energy offices spent a few hundred million dollars for R & D of motor vehicles and motor fuels:

	1991-low	*1991-high*
U. S. DOE R & D expenditures for motor fuels	100.0	300.0
U. S. DOE R & D expenditures for motor vehicles	100.0	100.0
State energy agency R & D expenditures for motor vehicles and motor fuels	50.0	100.0
Total government energy-agency expenditures related to motor-vehicle use (10^6 1991 $)	250.0	500.0

Note that, because these expenditures are so small, I do not bother to separate the capital-expenditure portion and annualize it explicitly. Instead, I assume that the range estimated above includes the annualized cost of any (probably tiny) capital portion of the total expenditures.

To estimate these expenditures for other years, I assume that expenditures (in nominal or current-year dollars) increased by 2.5% per year (low-cost case) to 4.0% per year (high-cost case).

7.10 MOTOR-VEHICLE RELATED COSTS OF OTHER GOVERNMENT AGENCIES

The use of motor vehicles also might be responsible for government expenditures in other functional areas of the Census' *Government Finances* classification system: financial administration ($27.2 billion by all governments in fiscal year 1991), other government administration ($11.6 billion), hospitals ($63.8 billion), health ($39.0 billion), protective inspection and regulation ($6.0 billion), natural resources ($56.9

billion). In the following paragraphs I identify the motor-vehicle-related activities in each functional area (on the basis of the description in the Census' *Classification Manual*, 1992), and discuss my treatment of them.

Financial administration includes the licensing and tax collection activities of motor-vehicle departments. However, these costs are reported in the FHWA's *Highway Statistics*, and listed here in Table 7-3. Financial administration also includes the tax collection of activities of other agencies that may be related indirectly to motor-vehicle use, but I presume that any such additional costs are small, and include them in my estimate of motor-vehicle-related costs of all other government agencies, at the end of this section. I ignore entirely any "second order" financial-administration costs, such as the cost of setting and administering the budget of a Department of Transportation.

Other government administration includes such things as the office of the chief executive or county administrator, overall planning and zoning, city councils, and so on. I assume that no portion of these are even indirect costs of motor-vehicle use.

Expenditures on health and natural resources include expenditures for resource development, energy R & D, and control of air and water pollution, a portion of which should be assigned to motor vehicle use. However, I have estimated all of these government costs separately, above.

Hospital costs attributable to motor vehicle use are included in my estimates (above) of government-paid costs of motor-vehicle accidents.

Protective inspection and regulation includes, among other things, motor-vehicle inspection and weighing unless handled by a police agency. However, the cost of this is reported in the FHWA's *Highway Statistics*, and listed here Table 7-3.

However, it is not clear if the motor-vehicle-related cost of the Interstate Commerce Commission is included in FHWA's *Highway Statistics*.

The upshot is that there do not appear to be any significant, additional, motor-vehicle-related expenditures by public agencies. I assume a token amount of $50 to $100 million/year, for all years.

7.11 MILITARY EXPENDITURES RELATED TO THE USE OF PERSIAN-GULF OIL BY MOTOR VEHICLES

7.11.1 Overview of Analysis for 1991

In this section, I seek to answer the question: "If the U.S. highway transportation sector did not use oil, how much would the U.S. federal government reduce its military commitment in the Persian Gulf?" The full analysis is presented in Report #15, and summarized briefly here. (Note that the cost-estimation method of section 7.1 is not used here.)

The analysis goes in four parts. First, we explain that the U.S. protects its "oil interests" in the Persian Gulf primarily to prevent supply disruptions and sudden price rises and the attendant macroeconomic problems. We cite evidence (including statements by the Joint Chiefs of Staff) that the U.S. Congress and the military do indeed plan and budget military operations for the Persian Gulf on account of U.S. oil interests there. We review and rebut arguments that the U.S. has other interests in the region more important than oil.

Second, we review the best available estimates of the amount of that the U.S. military spends to protect U .S. interests in the Persian Gulf. As part of the review we address the difficult question of how to allocate joint costs to particular programs. We focus on three studies: an analysis by Ravenal (1991) and an analysis by Kaufmann and Steinbruner (1991), and a report by the U.S. General Accounting Office (GAO) (1991) of estimates by the Department of Defense (DOD). The DOD and the GAO (1991) ignore the cost of any program that is targeted to more than one region, and consequently estimate that the U.S. spends less than $1 billion per year to protect the Persian Gulf. By contrast, Kaufmann and Steinbruner (1991) and Ravenal (1991) allocate joint costs to all programs, and estimate that the U.S. spends at least $50/billion per year on the Persian Gulf. We explain why we believe that Kaufmann and Steinbruner's (1991) and Ravenal's (1991) estimates are more accurate.

Third, we consider whether any of the economic assistance granted to countries of the Middle East is related to U.S. oil interests in the region. We show that most of this assistance goes to Israel and Egypt, and probably is not motivated by a desire to protect U.S. oil interests in nearby Arab countries.

Finally, we work "down" from our estimate of the cost of defending all U.S. interests in the Persian Gulf towards an estimate of the military cost of using oil in highway transportation. This proceeds in several steps: i) estimate how much military expenditure would be foregone if there were no oil in the Persian Gulf region; ii) estimate how much would be foregone if the U.S. did not produce or consume oil from the Persian Gulf, but other countries still did; iii) estimate how much would be foregone if U.S. producers had investments in the Gulf, but the U.S. did not consume any oil at all; iv) and lastly, estimate how much would be foregone if motor vehicles in the U.S. did not use oil, but other sectors still did and the U.S. (and other countries) still produced and consumed oil from the Gulf. This last is the bottom line of our analysis. The analysis of these steps generally is illustrative, not rigorously quantitative. In the end, we estimate that if U.S. motor vehicles did not use petroleum, the U.S. would reduce its defense expenditures in the long run by roughly $1 to $9 billion dollars per year[22]. Table 7-22 allocates this cost to six classes of motor vehicles, on the basis of the amount of oil consumed in each class (see Report #10 for details about cost allocation).

Note that we have not estimated the military cost of defending oil or infrastructure interests in other parts of the world. Nor have we estimated the

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[22]Because of the uncertainty in estimating this range, and the difficulty of determining how much of the relevant military capital really is a public good, I have not explicitly estimated and annualized the capital-cost portion of the total expenditure. To the extent that there is a significant opportunity cost of military capital related to motor-vehicle use, I will have underestimated the total annualized cost.

Note too that this is a cost not of all fuel consumption, nor even of importing oil generally, but rather of using Middle-East oil specifically "residual" cost of "uncontrolled" military threats attributable to oil use in transportation (except to the extent that the threat of an oil supply disruption is a residual). In effect, we treat military expenditures as a "control" cost (analogous to the cost of pollution-control equipment) that might or might not be optimal, but do not estimate the residual threat (analogous to the effect of pollutants emitted after control)[23].

7.11.2 Estimates for years other than 1991

In the previous section we summarize our estimate of military-expenditures related to the use Persian-Gulf oil for motor vehicles in 1991. Ideally, to estimate expenditures in other years, we would use the same methods used in the 1991analysis, but with data on military expenditures and motor-vehicle shares specific to the year of interest. This however is beyond our scope here. Instead, we will assume simply that the military-expenditure cost in any year Y is equal to the cost estimated for 1991 multiplied by an annual rate of change factor:

$$MME_Y = MME_{1991} \cdot (MEF)^{Y-1991}$$

where:

Y = year of interest
MME_Y = military expenditures related to the use of Persian Gulf oil for motor vehicles in year Y ($)
MME_{1991} = military expenditures related to the use of Persian Gulf oil for motor vehicles in 1991 (section 7.10.1; Table 7-22)
MEF = the annual rate of change in the motor-vehicle-related military expenditure (1+%change; discussed below)

We assume that the annual rate of change factor is related to changes in total defense expenditures. Table 3.16 of the NIPA

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[23] Owen (2004) also argues that defense costs are "control" costs, but then suggests that because they are control costs (rather than "damage" costs), and because control costs are not a good proxy for damage costs, they should *not* be counted as external costs in a social-cost analysis. However, this is true *only* if one uses defense expenditures as a proxy for estimating the "damages" that remain in spite of the defense expenditures. But since to our knowledge nobody does this, Owen's (2004) critique is academic. In fact, contrary to what Owen (2004) implies, public-sector defense expenditures that are related to the use of motor-fuel but not included in the price of motor fuel *are* properly included in any estimate of the social cost of motor fuel, whether the expenditures are called "control costs," "external costs," or something else. Furthermore, a complete social-cost estimate would include, *in addition*, the value of any energy-security-related global "damages" that remain after the application of the defense or "control" expenditures (such as human suffering due to instability or threat of war related to oil use). Thus, the social cost comprises private-sector costs, plus public-sector "control" costs, plus uncontrolled or "residual" damages.

(www.bea.gov/bea/dn/nipaweb/index.asp) shows U. S. national defense expenditures from 1970 to 2003. Since expenditures from 2001 to 2003 are inflated by the Afghan and Iraq wars, which we've accounted for already in our estimates in Report #15, we consider expenditures from 1970 to 2000. The annual rates of change in total defense expenditures over various periods from 1970 to 2000 are as follows:

1970-1980	1980-1990	1990-2000	1970-2000	1980-2000
1.062	1.079	1.004	1.048	1.041

From 1990 to 2000, which is the main period of interest, defense expenditures (in nominal, or current-year dollars) barely rose at all. In the low cost case I assume a rate of change of 0.5%/year, and in the high-cost case I assume 2.5%/year.

7.12 THE ANNUALIZED COST OF THE STRATEGIC PETROLEUM RESERVE: INVESTMENT, OPERATION AND MANAGEMENT, AND OIL-HOLDING COSTS

7.12.1 Background

The Energy Policy and Conservation Act of December 22, 1975 declared a U. S. policy to establish a Strategic Petroleum Reserve (SPR) of up to one billion barrels of petroleum products, to reduce the impacts of a severe energy supply interruption and to carry out the obligations of the United States under the International Energy Program (Office of Strategic Petroleum Reserve, 1996). At the beginning of 1993 the SPR had a capacity of 750 million barrels, and planning was underway for an additional 250 million barrels of capacity (Office of Strategic Petroleum Reserve, 1993), to bring the capacity to the desired 1 billion barrels. However, in 1994 the Secretary of Energy announced that one of the storage facilities, Weeks Island, would be closed due to geotechnical problems (Office of Strategic Petroleum Reserve, 1996). In 1996, most of the oil at Weeks Island was transferred to other storage sites (Office of Strategic Petroleum Reserve, 1997). The closing of the Weeks Island facility reduced the overall storage capacity of the reserve from 750 to 680 million barrels (Office of Strategic Petroleum Reserve, 1996). As of 2005 the SPR had a capacity of 727 million barrels (www.fe.doe.gov/programs/reserves/spr/spr-facts.html).

Beginning in 1977, the SPR was filled steadily through 1990, and at the end of 1990 had 585.7 million barrels (Office of Strategic Petroleum Reserve, 1996). The first major use of the SPR was during Operation Desert Storm, at the beginning of 1991, when 17.2 million barrels of crude oil were delivered to 13 purchasers. The second series of sales occurred in 1996, when 28.1 million barrels were sold as directed by the Appropriations Act for fiscal years 1996 and 1997 (Office of Strategic Petroleum Reserve, 1997). After the year 2000 oil again was added to the SPR, and as of 2005 the SPR held 700 million barrels of oil (www.fe.doe.gov/programs/reserves/spr/spr-facts.html).

In this section, I first estimate the annualized cost of the entire SPR, using the method described in section 7.1.2. Then, I estimate the shape of the total cost function (cost versus activity; in equations 7-8 and 7-14). Finally, I estimate the motor-vehicle related fraction of the cost-relevant activity measure, which I assume is oil imported from the Middle East.

7.12.2 The social cost of the SPR

The social cost of the SPR is equal to the annualized replacement cost of the entire capital investment in the SPR, plus the cost of operating and managing the SPR, plus the cost of holding oil in the SPR. All three kinds of costs -- capital costs, O & M costs, and oil–holding costs -- can be estimated from data reported in the *Strategic Petroleum Reserve Annual Report* (Office of the Strategic Petroleum Reserve, 1996)[24] and other sources. The calculation is shown next, and documented in the following sections (all dollars are 1991, unless stated otherwise).

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[24]Leiby and Lee (1988) remind us that purchasing oil for or selling oil from the SPR could affect the world price of oil, depending on the amount purchased or sold at any given time, and on the relationship between price and supply or demand. These price affects could create additional costs or benefits of purchasing oil for or selling oil from the SPR. Historically, however, SPR purchases and sales probably have been too small to significantly affect the world price of oil. For example, the highest average daily fill rate over a year (336,000 bbls per day in 1981) was about 0.6% of the average daily world oil consumption rate in that year (Office of Strategic Petroleum Reserve, 1992; EIA, *International Energy Annual 1991*, 1992). Assuming a demand elasticity of price of less than 0.10 (Leiby and Lee, 1988, assume less than -0.10 for the price elasticity of demand), the increase in demand would have resulted in a price increase of less than 0.06%. Similarly, the delivery of 17.2 million barrels over a month and one half during Operation Desert Storm probably did not significantly affect the world oil price.

Leiby and Lee (1988) also point out that the SPR might prompt some foreign oil suppliers to play games in the world oil market, and thereby create additional "costs" or "benefits".

	low	high
1. The annualized cost of the total capital investment in the SPR (10^9 $/year) (equation 7-7; parameter values in Table 7-2)	0.100	0.151
2. The annual cost of operating and managing the SPR (10^9 $/yr)	0.196	0.196
3. Present value of post-1991 oil purchases and sales from SPR (10^9 $)	8.74	-0.23
4. Present value of all oil in the SPR in base year (1991) (10^9 $) (base-year quantity × base-year selling price)	10.74	10.74
5. The annualized cost of holding oil in the SPR (10^9 $/yr) (line 4 - line 3, annualized over the life of the SPR)	0.104	0.809
6. Grand total annual cost of SPR (10^9 $/yr) (line 1 + line 2 + line 5)	*0.400*	*1.155*
7. Motor-vehicle cost fraction (equation 7-13f)	0.13	0.57
8. Grand total cost of SPR assigned to motor vehicles (10^9 $/yr) (equation 7-1; line 6 × line 7)	*0.052*	*0.664*

7.12.3 Capital and operating and management costs of the SPR

In this subsection, I estimate the annualized capital and annual operating and management costs that would have been saved had the SPR been closed down in any base year Y_O (e.g., 1991). I estimate annualized capital costs by annualizing the total capital replacement value over the life of the capital. The capital replacement value, in turn is estimated on the basis of annual appropriations for the SPR. The annual operating and management cost is the difference between total appropriations and estimated appropriations for capital. (I assume that costs = expenditures = appropriations.)

The capital replacement value of the SPR can be estimated in two ways: with the usual method in this report (ACE/ARF in equation 7-7), or with a direct estimate of the total initial investment. In this analysis, the normal method of estimating the total capital replacement value is to divide the annual capital expenditure (ACE) by the fraction of the total capital replaced by the expenditure (ARF) (equation 7-7). In the case of the SPR, I estimate an annual average capital expenditure over the history of the SPR.

Data and methods. The *Annual Report* of the Office of the Strategic Petroleum Reserve (1992, 1996) and the DOE Office of Fossil Energy web site show fiscal-year appropriations for "management" of the SPR, and for "storage facilities development and operations" (Table 7-21). Unfortunately, they do not officially separate the "storage facilities" account into a capital account and an operations account. The first task, then, is to estimate the capital portion of appropriations for "storage facilities". The Office of Petroleum Reserves (1995) estimated that capital expenditures totaled $1.6 billion from 1976 to 2004. To spread= this total over the period, I assume that when the SPR was built in the late 1970s and early 1980s, most of the appropriation for facilities was for capital, but that afterwards, a much smaller portion of the facilities account was for capital (Table 7-21).

Assuming that expenditures are equal to appropriations, I estimate current-dollar capital expenditures by multiplying reported current appropriations for "storage facilities" by the assumed capital portion of the facilities account. Current-dollar O & M expenditures then are equal to the remainder of the appropriations for "storage facilities", plus appropriations for "management". I use the GNP price deflators to convert current-year dollars to base-year (e.g., 1991) dollars (Table 7-21).

The capital expenditures thus calculated averaged less than $150 million per year from 1976 to 2005 (in 1991 dollars; Table 7-21). This data series captures most of the relevant expenditures, because the initial investments in the SPR were expected to last to the year 2000 or so (Office of the Strategic Petroleum Reserve (1996). Assuming a life of 20 years[25], the annual replacement factor (ARF) would be 0.05, and the total capital replacement value would be $0.150/0.05 = $3 billion.

Table 7-21 also shows my estimate of the yearly operating and management costs for the SPR, in 1991$. Note that "low-cost" and "high-cost" refer to the bottom line social-cost totals. Table 7-2 shows the assumed values for the other parameters in the estimation of the annualized capital costs[26].

7.12.4 The annualized cost of holding oil in the SPR.

The cost of holding oil in the SPR, in year Y, is the difference between the total cost (or value) of all of the oil in the SPR in year Y and the *present value* (in year Y) of all oil sales after year Y. This difference *annualized* is the annualized cost of holding oil in the SPR in year Y[27].

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[25]the Office of the Strategic Petroleum Reserve (1996, 1997) notes that four of the oil-storage sites, completed in the early 1980s, were designed for an operational life of 20 years.

[26] One could argue that the calculation of the capital replacement value in the base year of 1991 should be adjusted to account for the downsizing of the SPR in 1994 due to the closing of the Weeks Island storage facility, because closing the entire SPR in 1991 would not have saved the full repair, re-investment, maintenance, operating, and management costs associated with the Weeks Island facility (which as it turns out was to be closed a few years after 1991 in any case). I do not make any such adjustment, because it would have an insignificant effect on total social costs.

[27]If we expect the oil in the SPR to appreciate in value at a rate *less* than the prevailing public discount rate, then it is better to sell the oil now and invest the money so as to receive a rate of return at least equal to the public discount rate, considerations of the *benefits* of the SPR aside.

Mead (1992) writes that "the oil storage cost consists primarily of the interest charge on the stored oil, plus a charge for developing and maintaining the storage facility. Some (perhaps all) of the interest cost will be offset by increasing prices of crude oil..." (p. 77). If oil were a purely depletable resource, with a constant cost of recovery over time, then the price of oil would increase at the prevailing interest rate. But oil is not such a resource, and hence its price behavior is more complicated (Baumol and Oates, 1988).

The total value of oil in the SPR in any year is the total revenue foregone from not selling the oil, which in turn is equal simply to the quantity of oil (bbls) in the SPR in year Y multiplied by the $/bbl selling price of the oil in year Y. The present value in year Y of post-year-Y oil sales is:

$$PVSPR_{Y_O} = \sum_{Y_O+1}^{Y_C} \frac{(QSPR_{Y-1} - QSPR_Y) \cdot PSPR_Y}{(1+i)^{Y-Y_O}}$$

where:

Y = year
Y_O = base year (e.g., 1991)
Y_C = year that SPR is closed (I assume 2020 in the low-cost case and 2035 in the high-cost case)
$PVSPR_{Y_O}$ = the present value in base year Y_O of all post-year Y oil sales from the SPR ($)
$QSPR_Y$ = the quantity of oil in the SPR at the start of year Y (bbl; discussed below)
$PSPR_Y$ = the value (price) of oil in the SPR at the start of year Y ($/bbl discussed below)
i = the discount rate (I assume that the real interest rate pertaining to public investment is 3%/year [low-cost case] to 7%/year [high-cost case] [see Report #2 of this social–cost series])

Thus, in order to estimate the annualized cost of holding oil in the SPR in year Y, we need two data series: the $/bbl selling price of oil from the base year Y_O to the assumed year of closing of the SPR (Y_C) , and the amount of oil in the SPR from year Y_O to Y_C (the difference in the amount of oil in the SPR between any two years being equal to net sales from the SPR between the two years). Part of these series will be historical data (from year Y_O to the present), and part will be projections (from the present to Y_C). As regards the projections, I posit two simple future scenarios of price and quantity. In the low-cost scenario, the real price of oil increases, the discount rate is low, and the oil is sold off early. In the high-cost scenario, the real price of oil decreases, the discount rate is high, and oil is held in the reserve for a relatively long time.

The $/bbl price of oil. We will start our price data series with the earliest base year Y_O for which we will do the analysis, 1991. In 1991 oil actually was sold from the SPR (in order to offset supply losses due to the Iraqi invasion of Kuwait) for $18.33/bbl ($315 million in proceeds from the sale of 17.2 million barrels; Office of the Strategic Petroleum Reserve, 1996). This selling price is consistent with the 1991 average refiner acquisition cost of $19.06 bbl (EIA, *Annual Energy Review 1996*, 1997), because the refiner acquisition cost includes the minor cost of transporting the oil from the place of purchase to the refinery gate, whereas the price of oil from the SPR does not[28] . Therefore, I assume that the relevant nominal selling price of oil in 1991 was $18.33/bbl. The actual input to the model is this nominal 1991-dollar amount converted to year-Y_O dollars using GDP implicit price deflators.

I assume that the selling price of oil from 1992 to 2004 (in year-Y_O dollars) would have been equal to the 1991 price (in year Y_O dollars) multiplied by the ratio of the real refiner acquisition cost in year Y to the real refiner acquisition cost in 1991 (composite of domestic and imported oil acquisition costs; EIA, *Annual Energy Review 2003*, 2004; *Monthly Energy Review May 2005*, 2005).

Beyond the year 2004 I assume two possible trajectories through the year of closing of the SPR: one in which the *real* price of oil increases by 1.2% per year (the low-cost case), and one in which the real price decreases by 1.5% per year (the high-cost case). These two scenarios are broadly consistent with the range of projections in the EIA's *Annual Energy Outlook 2005* (2005).

The amount of oil in the SPR. As indicated above, the present value of oil sold in the future depends on how much oil is sold, when, and for how much. Thus, to estimate the present value, we must project sales (as well as the selling price) of SPR oil from 1991 to the time the SPR is assumed to be closed. Actual oil sales and acquisitions from 1991 to 1996 are reported by the Office of the Strategic Petroleum Reserve (1996, 1997). The amount of oil in the SPR from 1997 to 2004 was provided by the Office of Petroleum Reserves (2005).

By August 2005 the SPR will be filled to its official capacity of 700 million barrels. I assume that after this there will be no more oil acquisitions, only oil sales[29]. As mentioned above, I establish a low-cost oil-sale scenario, in which the oil is sold off relatively early (at relatively high prices), and a high-cost scenario in which the oil is sold off relatively late (and at relatively low prices). Specifically, in the low-cost case, I assume that henceforth, no more oil is added to the reserve, and that oil is sold sporadically until the year 2013, after which the remaining oil is sold over four years (95 million barrels/year) and the SPR is closed, after the year 2016. In the high-cost case, I assume that there are no further sales or purchases until the year 2025, after which the oil is sold off at 1/10th per year through the year 2035, when the Reserve is closed.

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[28]The price of SPR oil does include all other fees and costs, including the Oil Spill Liability Trust Fund fee of $0.05/bbl (Council on Environmental Quality, 1992), the cost of transportation to the SPR (about $0.50/bbl, based on the difference between the landed cost of imports and the "free-on-board" cost of imports [EIA, *Annual Energy Review 1994*, 1995]), customs fees, Superfund fees, Jones-Act fees, and terminal, injection, and extraction costs of (about $1/bbl for these last six fees and costs, according to the Office of the Strategic Petroleum Reserve[Leiby and Lee, 1988]).

[29]Although the Omnibus Budget Reconciliation Act of 1986 required that the SPR be filled at a minimum rate of 75,000 bbls/day until 750 million barrels are in storage (Office of Strategic Petroleum Reserve, 1992), and the Energy Policy Act of 1992 included provisions to enlarge the SPR to 1 billion barrels (Office of the Strategic Petroleum Reserve, 1997), it appears that the current plan is for the SPR to remain at 700 million barrels.

In the high-cost scenario, the present value of the future oil sales is close to zero, because the oil is sold many years into the future, at a very low price, in the face of a relatively high discount rate. In the low-cost case, however, the present value of the future oil sales is close to the value of the oil in the base year, because the oil rises in value at a rate near the discount rate, and is sold off relatively early.

I subtract the present value so calculated from the value of the oil in the base year (1991), and annualize the resulting difference over the life of the SPR, using equation 7-3.

7.12.5 The shape of the cost/activity function

In order to determine just what "activity" the cost of the SPR should be related to, and *how* the activity is to be related, we first must understand the purpose and function of the SPR.

As noted above, the purpose of the SPR is to reduce the impacts of a severe energy supply interruption, and to carry out the obligations of the United States under the International Energy Program. Under this program, the U. S. must maintain strategic inventories of oil equivalent to 90 days of net imports. Although this strategic inventory apparently can include privately owned stocks (which presently exceed the publicly owned stock in the SPR), it seems that the intent of the program is to have a substantial federal inventory:

> As a member of the IEA, the U.S. is obligated to maintain strategic inventories equivalent to 90 days of net imports. The height of protection provided by the SPR occurred in 1985, when its inventory equaled 118 days of net imports. Since then, oil imports have increased, fill of the SPR ceased in 1994, and oil was sold in FY 1996 and FY 1997. The protection afforded by the SPR has now been reduced to 67 days of net imports. If private inventories are included, the total current import coverage is 152 days... Based on recent Energy Information Administration import estimates, the days of import protection from the SPR will decrease to 46 days in 2002, implying a significantly increased dependence on private stocks, over which the Federal Government has virtually no control, to meet our international obligations (Moler, 1997).

Since Moler's remarks, the days of import protection afforded by the SPR has declined to 59 (www.fe.doe.gov/programs/reserves/spr/spr-facts.html).

Given this testimony by Deputy Secretary of Energy Moler, it is reasonable to assume that the long-run cost of the SPR is some function of the amount of oil imported. Because oil supply from the Middle East is more likely to be disrupted than is oil from anywhere else, I assume that the cost of the SPR is particularly sensitive to the amount of oil imported from the Middle East.

If the SPR presently held the obligatory 90-days worth of oil imports, and if there were no value to having it hold more than 90-days worth, then one reasonably might assume that permanent reductions in oil imports would lead to proportional reductions in the holdings and capacity of the SPR. However, as noted above the SPR will supply only 59 days of imports. In this situation, it is not clear what the federal government will do if net imports decline substantially. On the one hand, the government might choose to keep the holding and capacity of the SPR the same, and increase the number of days of imports covered by the SPR inventory; on the other, it might choose to have the same number of days covered by private stock, and reduce the burden on the public stock. The remarks by Deputy Secretary of Energy Moler (1997), cited above, indicate that the U. S. is leery of relying heavily on private stocks, because the federal government cannot control them.

With these considerations, I assume that a reduction in imports of X% will result in a reduction of less than X% (but greater than 0%) in the capacity of the SPR. This means that the shape exponent k in equations 7-8 and 7-14 is less than 1.0. I assume 0.50 in the low-cost case, and 0.75 in the high-cost case.

7.12.6 The motor-vehicle share of cost-relevant activity (imports of Middle East oil)

If the long-run cost of the SPR is a function of the amount of oil imported, and especially of the amount imported from the Middle East, then a change in motor-vehicle use will affect the cost of the SPR by affecting imports of oil, especially imports from the Middle East. Thus, the final step in the analysis of the SPR cost attributable to motor-vehicle use is to estimate the change in imports (as a fraction of the total in 1991) due to a change in motor-vehicle use -- the ratio of motor-vehicle-related activity to total activity in equations 7-13 and 7-14.

Unfortunately, the relationship between motor-vehicle use and oil imports is not straightforward. At the margin, or even on average, the mix of domestic and imported crude oil used to make motor fuels depends on short-run and long-run production costs, contractual obligations, national laws and policies, the quality of the oil, transportation arrangements, corporate strategies, and other factors. The matter is quite complicated, and cannot be formally modeled here. Rather than attempt to model the extent to which imported oil, or oil imported specifically from the Middle East, is used to make motor fuel, I simply assume some reasonable upper and lower bounds.

As a point of reference, I note that if all crude oil and unfinished oil -- domestic, imported, and imported from the Middle East specifically -- simply were mixed randomly in a big pot before being input to refineries, then on average 14.0% of the crude and unfinished oil used by domestic refineries to make highway fuels would have been crude oil or unfinished oil imported from the Middle East (calculated from the data of Table 10-13b in Report #10). Given this, I assume that crude or unfinished oil imported from the Middle East constitutes anywhere from 7% (low-cost case) to 21% (high-cost case) of the crude and unfinished oil used by U. S. refineries to make highway fuels. (Crude oil in finished fuels imported from the Middle East is accounted separately.) With these and other assumptions and estimates (Table 10-13b, Table 10-14), I calculate that petroleum from the Middle East in U. S. highway fuels is 24% to 68% of total petroleum imported from the Middle East to the U. S. (see Report #10 and Table 10-14 for details). In other words, I estimate that if motor-vehicle use were eliminated, imports of all petroleum from the Middle East would be reduced by 24% to 68%. I assume that these are the activity fractions (A_{TMV}/A_T) in equation 7-13 applied to the SPR.

7.12.7 Results of the analysis

As shown above, and in Table 7-22, the annual motor-vehicle-related cost of the SPR probably does not exceed $1 billion, and may be trivial. Of course, with different assumptions the results would be different, but not *much* different. I analyzed several other scenarios[30], but in no cases did the motor-vehicle-related total significantly exceed about $1 billion. The final allocation to six classes of motor vehicles is shown in Table 7-22.

7.13 TAX SUBSIDIES OR PENALTIES TO PRODUCERS AND USERS OF HIGHWAYS, VEHICLES, FUELS, AND RELATED SERVICES

7.13.1 Is there a rationale for assuming that general tax "subsidies" represent unpaid costs?

The tax code does not treat everyone and every business the same way. For example, some products are exempt from sales tax, and some producing activities are allowed special deductions that reduce tax liability. As a result, some people and businesses pay more or less tax, in total and per unit of income or value than do others. Is this preferential tax treatment relevant to the analysis of the cost of public-sector infrastructure and services related to motor-vehicle use?

Some analysts (e.g., Lee, 1995; Litman, 1997) have classified as a social cost the difference between some baseline rate of taxation and the actual rate of taxation applied to the production and use of motor-vehicle goods, services, or infrastructure. Typically, these analysts base their estimates of such so-called "tax subsidies" on the results of detailed studies of preferential tax treatment for oil production (e.g., Cone et al., 1980; Heede et al., 1985; EIA, *Federal Energy Subsidies*, 1992; Koplow, 1993; see Report #18). The original studies of preferential tax treatment start from the premise that there is a baseline amount, or rate, at which an entity or activity *should* be taxed, and with respect to which deviations constitute a tax subsidy (sometimes called a "tax expenditure") (e.g., Cone et al., 1980; Heede et al., 1985; EIA, *Federal Energy Subsidies*, 1992). For example, the recent EIA report (*Federal Energy Subsidies*, 1992) states that "tax expenditures exist when actual tax treatment for particular kinds of taxpayers deviates from standard tax treatment" (p. 21), although "there is disagreement as to what constitutes standard tax treatment..." [p. 21].)

Estimates of tax expenditures certainly are pertinent to analyses of government finances, which are interesting in their own right. But is there any basis for counting tax subsidies (expenditures) as an economic cost of motor-vehicle use? Those who count tax subsidies as a social cost argue that general government services, such as health,

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[30]For example, I did the analysis using the EIA's 1992 (*Annual Energy Outlook, 1992*, 1992) projections of the annual rate of change of the real world price of oil, instead of its 1998 projections: 1.6% in the low-cost case, and 3.8% in the high-cost case. With these projections, the SPR "holding cost" of course is lower.

education, and defense, must be paid for by general taxes, set at a "fair" or "economically neutral" baseline rate, and that any deviation from this baseline rate -- for example, the exemption of gasoline sales from the sales tax -- constitutes an economic cost to society. However, I object to this on two grounds.

First, the general government services that are financed by general taxes are not a cost of motor-vehicle use in the economic sense of "opportunity cost". If one expands motor-vehicle use and the motor-vehicle infrastructure a lot, one eventually will devote more resources to maintaining and policing highways, but one will not devote more resources to education or national defense, all else equal, because these are [quasi-] public goods. Strictly speaking, no portion of the money cost of any public good is a cost of any particular transportation system. In a social-cost framework, public goods should be classified a separate account, to be financed, ideally, by minimally distortionary taxes, such as lump-sum charges.

Second, any tax payment, whether greater or less than some arbitrary baseline, is in the first instance a transfer from producers or consumers to the government, and not representative of a net resource cost. Even if the *only* distortion in the U.S. tax system were the exemption of gasoline from the sales tax, the true money welfare cost to society of failing to tax gasoline would *not* be the amount of the tax revenue foregone, but rather the probably much smaller difference between the total deadweight loss with and without the gasoline sales tax (given a fixed tax collection). And given that the U.S. tax system is distorted (non-optimal) in myriad ways, the general theory of the second best (Lipsey and Lancaster, 1956-57; Davis and Whinston, 1965; Laffont, 1990) tells us that one cannot even be sure that failing to tax gasoline, in our wildly distorted system, is on balance costly rather than beneficial.

For these reasons, I do not include tax expenditures in this analysis, which concerns the cost of public infrastructure and services related to motor-vehicle use. However, because government finance related to motor-vehicle use is interesting in itself, we have written a separate report on tax expenditures related to motor-vehicle use (#18 in this social-cost series). That report establishes an analytical framework for tax expenditures, reviews the literature, and provides some original estimates.

7.13.2 A note on the difference between tax expenditures and "subsidies" in general

It should be clear that my argument against counting tax expenditures as an economic cost of motor-vehicle use does not apply to anything that anyone might ever have called a "government subsidy". For example, past studies of "subsidies" to energy production (e.g., Cone et al., 1980; Heede et al., 1985; EIA, *Federal Energy Subsidies*, 1992; Koplow, 1993; see Report #18) have included in their definition of "subsidy" the cost of government regulation and research and development, to the extent that the government expenditures were not covered by user charges. There is no question that agency outlays can be opportunity costs of motor-vehicle use: for example, if there were no motor-vehicle use, there would be no EPA Office of Mobile Sources[31], and hence no

[31]Ignoring the small amount of attention to non-highway mobile sources.

funds devoted to this office. In this analysis I distinguish these agency outlays from tax expenditures, primarily because of the important conceptual difference just implied: the former clearly are an opportunity cost of motor-vehicle use[32], whereas the latter are not. I estimate these government regulatory and R & D costs elsewhere in this Report.

7.14 SUMMARY

The results of the analysis in this report are summarized in Table 7-23. The Table shows the costs of a 10% change in motor-vehicle use (ΔMVU = 0.10 in equation 7-14), as well as the costs of all motor-vehicle use (i.e., for a change in motor-vehicle use of -100%, ΔMVU = 1.0 in equation 7-14). In several cases, the cost of a 10% change in motor-vehicle use is estimated to be less than 10% of the cost of a 100% change, because the shape exponent k relating cost to activity (equations 7-8 and 7-14) is assumed to be less than 1.0. (The shape exponent r, in equations 7-13 and 7-14, is assumed to be 1.0 in all cases.)

Note that the cost items in Table 7-23 have been organized to facilitate comparison with FHWA estimates of expenditures for highways and to delineate the key adjustments we have made to the FHWA estimates. Note too that we have distinguished "direct" from "indirect" expenditures, for the purpose of comparing goverment expenditures with user tax-and-fee payments in Report #17.

Total costs can be allocated to different vehicle classes (light-duty gasoline autos, light-duty gasoline trucks, heavy-duty diesel trucks, and so on) on the basis of allocation factors presented in Report #10 and Report #1. For example, the maintenance and repair cost of highways can be allocated on the basis of ton-miles of travel per axle. The cost of the highway patrol, and other police activities, can be allocated on the basis of the number of vehicles, or the number of vehicle-miles of travel. The motor-vehicle related costs of water treatment can be allocated on the basis of oil consumption. All these allocation factors, and others, for six classes of vehicles, are shown in Tables 1-A5 (Report #1) and 10-3 (Report #10).

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[32]Two qualifications here. First, the EPA budget would be foregone only in the long run, and only as a result of changes in government policy. Second, the true value or resource cost of the EPA's services might not be equal to the agency expenditures.

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TABLE 7-1. DIRECT GOVERNMENT EXPENDITURES ON HIGHWAYS, POLICE PROTECTION, JUDICIAL SYSTEM, CORRECTIONS, AND FIRE PROTECTION, 1989-2003 (10^9 NOMINAL $)

A. FEDERAL GOVERNMENT (FISCAL-YEAR DATA)

	Highways[a]		Police[b]		Legal/judicial[c]		Corrections[d]		Fire[e]	
	Capital	*Total*	*Capital*	*Total*	*Capital*	*Total*	*Capital*	*Total*	*Capital*	*Total*
2003	0.25	0.97	1.24	20.79	0.39	7.51	0.50	7.96	0.00	0.00
2002	0.25	0.97	1.24	20.90	0.35	6.75	0.44	7.09	0.00	0.00
2001	0.20	0.80	1.15	19.30	0.33	6.42	0.41	6.57	0.00	0.00
2000	0.14	0.53	1.10	18.55	0.26	5.01	0.32	5.19	0.00	0.00
1999	0.16	0.62	0.95	15.99	0.23	4.35	0.23	3.63	0.00	0.00
1998	0.16	0.62	0.88	14.82	0.21	4.03	0.15	2.42	0.00	0.00
1997	0.16	0.62	0.75	12.69	0.19	3.70	0.17	2.77	0.00	0.00
1996	0.07	0.27	0.53	8.96	0.27	5.22	0.28	4.50	0.00	0.00
1995	0.07	0.27	0.44	7.33	0.27	5.22	0.28	4.50	0.00	0.00
1994	0.18	0.71	0.44	7.36	0.26	4.90	0.24	3.81	0.00	0.00
1993	0.16	0.62	0.44	7.36	0.24	4.68	0.15	2.42	0.00	0.00
1992	0.31	0.81	0.46	6.70	0.24	4.42	0.09	2.41	0.00	0.00
1991	0.14	0.67	0.40	6.17	0.26	4.00	0.07	1.94	0.00	0.00
1990	0.18	0.86	0.32	5.34	0.16	3.28	0.06	1.59	0.00	0.00
1989	0.17	0.78	0.20	4.95	0.11	2.95	0.24	1.30	0.00	0.00

B. STATE GOVERNMENT (FISCAL-YEAR DATA)

	Highways[a]		Police[b]		Legal/judicial[c]		Corrections[d]		Fire[e]	
	Capital	*Total*	*Capital*	*Total*	*Capital*	*Total*	*Capital*	*Total*	*Capital*	*Total*
2003	48.72	72.45	0.89	9.86	0.60	14.94	1.61	36.94	0.00	0.00
2002	49.27	71.25	1.03	9.41	0.68	14.42	1.93	36.47	0.00	0.00
2001	44.76	66.44	0.80	8.87	0.54	13.47	2.22	35.81	0.00	0.00
2000	41.65	61.94	0.77	8.58	0.49	12.37	2.51	33.04	0.00	0.00
1999	37.99	56.24	0.70	7.81	0.46	11.39	2.52	30.77	0.00	0.00
1998	35.01	51.97	0.64	7.17	0.41	10.15	2.39	28.68	0.00	0.00
1997	32.85	48.77	0.60	6.67	0.34	8.57	2.26	27.12	0.00	0.00
1996	32.20	47.55	0.58	6.50	0.32	8.11	2.10	25.29	0.00	0.00
1995	31.69	46.89	0.52	5.73	0.30	7.53	2.75	24.09	0.00	0.00
1994	29.99	43.81	0.48	5.32	0.28	6.90	2.17	21.27	0.00	0.00
1993	28.21	42.06	0.45	4.96	0.27	6.64	1.85	19.09	0.00	0.00
1992	27.76	40.48	0.28	4.86	0.22	6.33	2.28	18.40	0.00	0.00
1991	26.82	38.91	0.35	4.79	0.21	5.92	2.70	17.81	0.00	0.00
1990	24.85	36.46	0.37	4.49	0.16	5.44	2.40	15.90	0.00	0.00
1989	24.59	35.32	0.40	4.14	0.14	4.98	2.12	13.83	0.00	0.00

C. Local government (fiscal-year data)

	Highways[a]		Police[b]		Legal/judicial[c]		Corrections[d]		Fire[e]	
	Capital	*Total*	*Capital*	*Total*	*Capital*	*Total*	*Capital*	*Total*	*Capital*	*Total*
2003	16.80	45.24	2.59	57.50	0.88	17.52	1.19	18.53	2.17	27.85
2002	16.90	44.22	2.69	55.08	0.76	16.82	1.42	18.22	2.16	25.98
2001	15.35	40.80	2.28	50.72	0.79	15.73	1.21	16.56	1.95	24.97
2000	14.79	39.39	2.17	48.22	0.73	14.66	1.27	15.77	1.80	23.10
1999	13.92	36.78	2.05	45.56	0.70	13.93	1.29	14.83	1.66	21.26
1998	13.06	35.24	1.95	43.31	0.67	13.42	1.17	13.80	1.58	20.27
1997	12.33	33.29	1.84	40.95	0.65	13.08	1.09	12.83	1.51	19.41
1996	11.26	31.54	1.72	38.18	0.62	12.34	0.99	12.22	1.38	17.71
1995	10.87	30.22	1.59	35.32	0.58	11.63	1.07	11.77	1.33	17.01
1994	9.51	28.26	1.50	33.32	0.55	10.97	1.12	11.00	1.26	16.12
1993	8.74	26.08	1.40	31.19	0.52	10.31	1.29	10.52	1.23	15.80
1992	9.27	26.21	1.15	29.68	0.41	10.03	1.61	10.30	0.97	14.36
1991	9.59	26.03	1.20	27.98	0.50	9.46	1.49	9.55	0.99	13.80
1990	9.02	24.59	1.16	26.09	0.56	8.66	1.41	8.73	1.12	13.19
1989	8.17	22.78	0.98	23.63	0.38	7.61	1.12	7.37	0.87	11.93

D. Federal, State and local government total (fiscal –year data)

	Highways[a]		Police[b]		Legal/judicial[c]		Corrections[d]		Fire[e]	
	Capital	*Total*	*Capital*	*Total*	*Capital*	*Total*	*Capital*	*Total*	*Capital*	*Total*
2003	65.77	118.67	4.71	88.15	1.86	39.97	3.29	63.43	2.17	27.85
2002	66.42	116.44	4.96	85.39	1.79	37.98	3.79	61.78	2.16	25.98
2001	60.31	108.03	4.23	78.88	1.66	35.63	3.84	58.94	1.95	24.97
2000	56.58	101.87	4.05	75.35	1.49	32.04	4.10	54.00	1.80	23.10
1999	52.06	93.64	3.70	69.36	1.38	29.67	4.03	49.23	1.66	21.26
1998	48.23	87.83	3.48	65.29	1.29	27.60	3.72	44.90	1.58	20.27
1997	45.35	82.68	3.20	60.31	1.19	25.35	3.52	42.71	1.51	19.41
1996	43.52	79.36	2.84	53.64	1.21	25.68	3.37	42.01	1.38	17.71
1995	42.63	77.37	2.54	48.39	1.16	24.39	4.10	40.35	1.33	17.01
1994	39.68	72.77	2.42	46.00	1.08	22.77	3.53	36.08	1.26	16.12
1993	37.11	68.75	2.29	43.50	1.03	21.63	3.29	32.04	1.23	15.80
1992	37.34	67.50	1.89	41.25	0.86	20.77	3.97	31.11	0.97	14.36
1991	36.55	65.61	1.94	38.94	0.97	19.38	4.25	29.30	0.99	13.80
1990	34.05	61.91	1.86	35.92	0.87	17.38	3.87	26.22	1.12	13.19
1989	32.92	58.87	1.58	32.72	0.63	15.54	3.48	22.50	0.87	11.93

E. FEDERAL, STATE AND LOCAL GOVERNMENT TOTAL (CALENDAR-YEAR ESTIMATES)

	Highways[a]		Police[b]		Legal/judicial[c]		Corrections[d]		Fire[e]	
	Capital	*Total*	*Capital*	*Total*	*Capital*	*Total*	*Capital*	*Total*	*Capital*	*Total*
2003	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.
2002	66.10	117.55	4.84	86.80	1.82	38.79	3.53	62.39	2.17	26.92
2001	63.35	112.19	4.57	81.73	1.72	36.72	3.81	60.23	2.05	25.47
2000	58.43	104.88	4.13	76.93	1.56	33.48	3.95	56.12	1.87	24.04
1999	54.33	97.77	3.84	71.71	1.43	30.69	4.04	51.22	1.73	22.18
1998	50.15	90.74	3.57	67.03	1.33	28.55	3.86	46.76	1.62	20.77
1997	46.79	85.26	3.30	62.27	1.23	26.39	3.63	43.89	1.55	19.84
1996	44.41	80.93	2.96	56.04	1.22	25.89	3.48	42.79	1.45	18.56
1995	43.08	78.37	2.66	50.61	1.18	25.04	3.74	41.18	1.35	17.36
1994	41.19	75.18	2.48	47.20	1.11	23.50	3.81	38.04	1.29	16.57
1993	38.39	70.74	2.35	44.75	1.05	22.15	3.39	33.71	1.24	15.96
1992	37.26	68.18	2.10	42.21	0.94	21.13	3.62	31.57	1.10	15.08
1991	36.90	66.52	1.90	39.96	0.92	19.97	4.11	30.09	0.98	14.08
1990	35.31	63.81	1.88	37.22	0.89	18.20	4.06	27.67	1.05	13.50
1989	33.48	60.37	1.68	34.22	0.74	16.38	3.72	24.29	0.99	12.56

n. e. = not estimated, FY = Fiscal Year, CY = Calendar year. Fiscal year *Y* ends on June 30th of *Y*, with the following major exceptions: the fiscal year for the Federal Government, the state government of Alabama, and the state government of Michigan ends on September 30; the fiscal year for the state government of Texas ends on August 30; and the fiscal year for the state government of New York ends on March 31. The calendar year of course ends on December 31.

A direct expenditure is defined as "payments to employees, suppliers, contractors, beneficiaries, and other final recipients of government payments -- i.e., all expenditure other than intergovernmental expenditure" (Bureau of the Census, *Government Finances: 1989-90*, 1991, p. A-2). Capital expenditures include those for construction of buildings, roads, and other improvements; for purchase of equipment, land, and existing structures; and for additions, replacements, and major alterations (Bureau of the Census, *Government Finances: 1989-90*, 1991).

Local governments include counties, cities, municipalities, townships, school districts, fire districts, and other special districts.

Sources:

- FY 1989 to FY 1992, capital and total expenditures, federal, state, and local governments (Table parts A, B, and C): Bureau of the Census, *Government Finances: 1989-90* (1991); *Government Finances: 1990-91* (1993); and *Government Finances: 1991-92* (1996).
- FY 1993 to FY 2003, total expenditures, state and local governments (Table parts B and C): Bureau of the Census government finance data available on the web at http://www.census.gov/govs/www/estimate.html.

- FY 1993 and 1994, total expenditures, federal government (Table part A): Bureau of the Census government finance data available at: http://www.census.gov/govs/fedfin/federal.txt.
- FY 1995 to FY 2003, total expenditures, federal government (Table part A): After FY 1994 the Census apparently stopped collecting or reporting federal government expenditures by functional area (e.g., police protection). However, Table 3.16 of the National Income Product Accounts (NIPA) of the Bureau of Economic Analysis (BEA) does report calendar-year expenditures by the federal government for "police," "fire," "law courts," and "prisons" (www.bea.gov/bea/dn/nipaweb/index.asp). The amounts shown in NIPA Table 3.16 for CYs 1989 to 1993 do not appear to correspond to the Census amounts shown for FYs 1989 to 1994, perhaps because of different definitions of the functional categories. Therefore, rather than use the NIPA Table 3.16 data directly, we applied the year-to-year percentage changes from the NIPA Table 3.16 data to our Census estimates beginning with the last year for which the Census provided data on federal expenditures by function (FY 1994).
- FY 1993 to FY 2003, capital expenditures for highways and corrections, state and local governments (Table parts B and C): Bureau of the Census government finance data available on the web at http://www.census.gov/govs/www/estimate.html.
- FY 1993 to FY 2003 except FY 2002, capital expenditures for police, judicial/legal, and fire, state and local governments: I estimated capital expenditures as a fraction of total expenditures on the basis of the capital-expenditure fractions calculated for FY 1989 to 1992 and FY 2002.
- FY 2002, capital expenditures for police, judicial/legal, and fire, state and local governments, (Table parts B and C): Public-use data file containing complete government finance data from the Bureau of the Census 2002 Census of Governments, available on the web at http://www.census.gov/govs/www/estimate02.html.
- FY 1993 to FY 2003, capital expenditures, federal government (Table part A): I estimated capital expenditures as a fraction of total expenditures on the basis of the capital-expenditure fractions calculated for FY 1989 to 1992.
- FY 1989 to FY 2003, capital and total expenditures, totals for all levels of government (Table part D): sum of estimates from Table parts A, B, and C.
- CY 1989 to CY 2003, capital and total expenditures, totals for all levels of government (Table part E): The calendar year total for year Y (CY_Y) is calculated from the fiscal year (FY) totals as follows:

$$CY_Y = 0.75 \cdot FedFY_Y + 0.25 \cdot FedFY_{Y+1} + 0.5 \cdot (StateFY_Y + LocalFY_Y) + 0.5 \cdot (StateFY_{Y+1} + LocalFY_{Y+1}).$$

If government expenditures increase from quarter to quarter, which generally they do, then this method slightly overestimates calendar-year expenditures, because expenditures in the last half of the fiscal year generally will be greater than expenditures in the first half, with the result that, in the case of state and local FYs, the weight on FY_Y should be slightly more than 0.50, and the weight on FY_{Y+1} slightly less.

[a]This category includes expenditures for streets, highways, toll roads, and related structures; highway garages and highway-administration buildings; street and highway planning and engineering, including related traffic engineering administered highway or public works agencies; street-lighting services; and snow and ice removal. It does not include any costs

associated with policing streets or highways, public safety, parking, street cleaning, or public transit, or debt retirement or interest.

In my calculation of the annualized cost of roads, I use the FHWA *Highway Statistics* data, not the Census data shown here. However, the two sources appear to be close. The functions covered by the Census data (listed in the preceding paragraph) appear to be the same as those included in the FHWA's *Highway Statistics*, with a few identifiable exceptions: the FHWA includes expenditures on law enforcement and public safety related to highways (including vehicle inspection and weight enforcement), and on debt retirement and interest, but excludes expenditures on street lighting. When adjustments are made for these differences in coverage, the FHWA and the Census estimates appear to be reasonably close: for example, the FHWA (*Highway Statistics 1991*, 1992) estimates expenditures of $61.94 billion for calendar year 1990, excluding expenditures for law enforcement and public safety and debt retirement and interest.

[b]Federal agencies included in this category are: the Federal Bureau of Investigation; Customs Service, Drug Enforcement Agency, Bureau of Alcohol, Tobacco, and Firearms; and Secret Service.

The Bureau of Justice Statistics (*Sheriffs' Departments*, *1990*, 1992), reports operating expenditures of $20.6 billion by local police departments, $9.1 billion by Sheriff's departments, $8.1 billion by special police agencies, and $3.7 billion by State police agencies, for a total of $41.6 billion, in fiscal year 1990. However, the BJS probably includes agencies (most likely under the "special police" category) not included by the Census.

[c]According to the Census, judicial and legal expenditures are for courts, law libraries, juries, witness fees, legal departments, general counsels, prosecuting and district attorneys, public defenders, payments for court-appointed lawyers, and other court-related activities. For local governments, it includes probate functions.

[d]According to the Census, expenditures on corrections are for prisons, reformatories, houses of correction, pardon, probation, and parole. Expenditures for police "lock-ups" or jails used for detention of persons awaiting arraignment are not included here, but are included under "police protection". However, expenditures on jails holding persons awaiting trial or serving short-term sentences for minor offenses are included here.

[e]States do spend money to fight forest fires, but in the Census' *Government Finances* these expenditures are classified under "forestry". As expenditures on forest fires are not related to motor-vehicle use, I do not bother to ferret these expenditures out.

TABLE 7-2. ASSUMED AND ESTIMATED PARAMETER VALUES IN THE CALCULATION OF THE MOTOR-VEHICLE-RELATED COST OF PUBLIC INFRASTRUCTURE AND SERVICES, 1991

	Cap. exp. (10^9 \$/yr) (ACE)[a]		O & M exp. (10^9 \$/yr) (OME)[a]		Reported land cost (RLC)[b]		True land cost (TLC)[c]		Capital life (years) (t)[d]	
	low	*high*	*low*	*high*	*low*	*high*	*low*	*high*	*low*	*high*
Highways	40.1	40.1	36.5	36.5	0.08	0.10	0.20	0.30	35	50
Commercial city parking	0.3	0.3	0.5	0.5	0.19	0.19	0.23	0.25	35	45
Highway patrol and safety	0.5	0.5	6.6	6.6	0.15	0.25	0.17	0.33	45	60
Other police protection	1.9	1.9	38.1	38.1	0.15	0.25	0.17	0.33	45	60
Fire protection	1.0	1.0	13.1	13.1	0.15	0.25	0.17	0.33	45	60
Courts	0.9	0.9	19.1	19.1	0.15	0.25	0.17	0.33	45	60
Prison, probation, parole	4.1	4.1	26.0	26.0	0.15	0.25	0.17	0.33	45	60
Pollution regul., control										
Air	0.2	0.2	1.5	1.5	0.15	0.25	0.17	0.33	45	60
Water	11.4	11.4	13.4	13.4	0.10	0.14	0.11	0.18	35	50
Solid Waste	0.0	0.0	12.0	12.0	0.22	0.26	0.24	0.34	35	50
Other	0.0	0.0	0.8	0.8	0.15	0.25	0.17	0.33	45	60
Strategic Petrol. Reserve	0.14	0.18	0.10	0.09	0.08	0.10	0.08	0.12	20	20

	Discount rate (i)[e]		Ann. cap. (10^9 \$/yr) (ACC)[f]		Cost exponent (k)[g]		MV activity fraction (A_{TMV}/A_T)[g]		Change in cost (ΔACM)[h]	
	low	*high*	*low*	*high*	*low*	*high*	*low*	*high*	*low*	*high*
Highways	0.03	0.07	64.4	151.9	1.00	1.00	0.99	0.99	0.99	0.99
Commercial city parking	0.03	0.07	0.5	1.0	1.00	1.00	1.00	1.00	1.00	1.00
Highway patrol and safety	0.03	0.07	0.8	2.1	0.60	0.80	1.00	1.00	1.00	1.00
Other police protection	0.03	0.07	3.4	8.7	0.65	0.85	0.04	0.12	0.02	0.10
Fire protection	0.03	0.07	1.7	4.5	0.30	0.60	0.15	0.25	0.05	0.16
Courts	0.03	0.07	1.6	4.2	0.98	0.98	0.24	0.27	0.23	0.27
Prison, probation, parole	0.03	0.07	7.3	18.8	0.98	0.98	0.12	0.14	0.12	0.14
Pollution regulation, control										
Air	0.03	0.07	0.3	0.8	1.00	1.00	0.30	0.37	0.30	0.37
Water	0.03	0.07	18.0	42.7	0.30	0.60	0.10	0.11	0.03	0.07
Solid Waste	0.03	0.07	0.0	0.0	1.00	1.00	0.04	0.08	0.04	0.08
Other	0.03	0.07	0.0	0.0	1.00	1.00	0.05	0.10	0.05	0.10
Strategic Petrol. Reserve	0.03	0.07	0.18	0.34	0.50	0.75	0.24	0.68	0.13	0.57

Cap. exp. = capital expenditure; O & M exp. = operating and maintenance expenditure; Ann. cap. = annualized capital cost; MV = motor-vehicle; regul. = regulation; Petrol. = petroleum.

Note that this table does not include three general expenditure categories: energy research and development for vehicles and fuels, other government agency costs, and military expenditures related to imported oil. I exclude these because costs in these categories are estimated directly, without using equation 7-14 or any of the methods of section 7.1. Hence, cost estimates in these categories do not involve the parameters shown in this table.

[a]From Tables 7-1 and 7-3, and other sources; see the discussions in the pertinent sections of the text. The values shown here are for 1991; when the analysis is done for other years, the actual values of ACE and OME for those years are used (e.g., from Table 7-1).

[b]These are my estimates, based on government capital expenditures for construction, equipment, and land and existing structures (Bureau of Census, 1992 Census of Governments, (electronic database, 1997). With the Census data, one can calculate expenditures on land and existing structures as a fraction of expenditures on all capital (construction + equipment + land + existing structures) in 1992:

Functional area	*(Land+existing structures)/(all capital)*
Airports	0.15
Correctional institutions	0.11
Other corrections	0.11
Fire	0.53
Judicial and legal	0.29
General public buildings	0.17
Highways (Census data)	0.12
Highways (FHWA data)	0.12
Toll highways (Census data)	0.08
Housing and community development	0.16
Natural resources	0.29
Parking	0.27
Police	0.55
Sewers	0.11
Solid Waste	0.31
Water supply	0.15
Electric power	0.22
Public mass transit systems	0.33

Note, though, that the fraction shown immediately above is not quite the same as the parameter RLC : the fraction shown above includes in the numerator expenditures on existing structures as well as land, whereas RLC includes expenditures on land only. (Existing structures include those that are condemned and torn down immediately to make room for new construction, as well as those bought for use.) Thus, to infer RLC from the fractions shown above, I must estimate and remove from those fractions expenditures on existing structures. Expenditures on existing structures undoubtedly vary greatly from functional area to functional area. Presumably, capital outlays for airports, prisons, and electric power plants include very little for existing structures, because these facilities usually are built new on undeveloped land. On the other hand, I expect that police often purchase existing structures rather than build new facilities.

I estimate values for RLC on the basis of these data and considerations. I assume that these estimates apply to all years, not just to 1991.

[c]Generally, I assume that the true land-cost fraction, TLC, is only 10% to 30% higher than the reported land-cost fraction, RLC, because I believe that most land costs are reported. An exception is the case of highways, because it appears that reported land costs for highways are much less than true land costs. For example, my own independent estimate of TLC for highways -- the ratio of the value of all land in highway right-of-way to the value of all highway capital (land + roadway) -- is 0.25 (based on the data of Tables 7.5 and 7.6), which is much higher than the RLC implied by the Census and FHWA data on land+existing structures, discussed above. See also the discussion in section 7.2.7. I assume that these estimates apply to all years, not just to 1991.

[d]My assumptions. Note that I assume that the reciprocal of the annual replacement factor, ARF, is equal to the life of the capital. This will be the case if the capital stock is in steady state, such that every year 1/t is replaced, where t is the lifetime. I assume that these estimates apply to all years, not just to 1991.

[e]My assumptions. See Report #2. I assume that these values apply to all analysis years, not just to 1991.

[f]Calculated using equation 7-7 without the addition of OME.

[g]See the discussions in the pertinent sections of the text. As mentioned in the text, I assume that in all cases, the activity exponent "r" is 1.0. I assume that these estimates apply to all years, not just to 1991.

[h]Calculated using equation 7-13f or 7-13g.

TABLE 7-3. EXPENDITURES REPORTED BY FHWA, 1971-2003 (10^6 NOMINAL $)

Year*	Capital outlay	Main-tenance	Admin., research	Police & safety	Debt & interest	*FHWA subtotal*
	a	*b*	*c*	*d*	*e*	*f*
2003	69,876	35,467	12,147	13,649	12,673	*143,812*
2002	68,175	33,180	10,695	11,672	12,198	*135,919*
2001	65,968	31,677	10,423	11,977	9,856	*129,900*
2000	61,323	30,636	10,020	11,031	9,688	*122,697*
1999	57,227	29,997	9,130	10,393	9,264	*116,011*
1998	52,308	28,173	8,523	9,445	9,526	*107,975*
1997	48,360	26,777	8,256	9,761	8,799	*101,953*
1996	46,810	25,564	8,445	8,897	8,366	*98,082*
1995	43,097	24,455	8,332	7,977	8,643	*92,504*
1994	42,379	23,553	8,376	7,673	8,211	*90,192*
1993	39,528	22,894	7,921	7,157	8,925	*86,425*
1992	38,309	22,224	7,719	7,088	8,210	*83,550*
1991	36,638	21,222	6,856	7,040	6,855	*78,611*
1990	35,151	20,365	6,501	7,235	6,156	*75,408*
1989	33,144	18,952	5,683	6,647	6,437	*70,863*
1988	32,884	19,109	4,961	6,108	5,506	*68,568*
1987	30,674	18,152	4,973	5,962	5,473	*65,234*
1986	29,179	17,643	4,677	5,549	5,299	*62,347*
1985	26,583	16,589	4,175	5,241	4,884	*57,472*
1984	23,079	15,008	3,604	4,937	4,052	*50,680*
1983	20,194	14,240	3,347	4,309	4,044	*46,134*
1982	19,018	13,319	3,152	4,068	3,736	*43,293*
1981	19,700	12,165	3,439	3,884	3,216	*42,404*
1980	20,305	11,445	3,022	3,824	3,167	*41,763*
1979	17,567	10,571	2,726	3,359	3,176	*37,399*
1978	14,910	9,785	2,590	3,160	2,961	*33,406*
1977	13,060	8,612	2,370	2,842	2,929	*29,813*
1976	13,893	7,735	2,209	2,633	2,801	*29,271*
1975	14,378	7,286	1,981	2,413	2,621	*28,679*
1974	13,094	6,573	1,857	2,061	2,524	*26,109*
1973	12,157	5,949	1,735	1,898	2,446	*24,185*
1972	12,268	5,433	1,600	1,671	2,220	*23,192*
1971	12,299	5,114	1,436	1,503	2,121	*22,473*
wt^g	*0.0*	*1.0*	*1.0*	*0.0*	*0.1*	*0.0*

Source: FHWA-estimated expenditures from 1971 to 1995 are from Table HF-210 of FHWA's *Highway Statistics*, *Summary to 1995* (1997) (see also FHWA, *Highway Statistics Summary to 1985*, 1987). Estimates for 1996 to 2003 are from Table HF-10 of FHWA's *Highway Statistics* (various years; available on the web at www.fhwa.dot.gov/policy/ohpi/hss/index.htm.) (see also data in FHWA Table HF-2). The expenditure categories are elaborated in the notes here and more fully in FHWA's *Highway Statistics* and *A Guide to Reporting Highway Statistics* (1990). The FHWA's Office of Highway Information and Management provided considerable additional details about what is and is not included in FHWA's estimates of expenditures and payments. Generally, statements here that are not referenced to FHWA publications or to my own calculations or assessments are based on information provided by the FHWA Office of Highway Management and Information. However, this does not necessarily imply that FHWA endorses the estimates presented here.

* According to the FHWA's *Highway Statistics* series (various years), *Highway Statistics*, *Summary to 1995* (1997), and *A Guide to Reporting Highway Statistics* (2005), some financial statistics are reported for fiscal years (ending at various times) and some are reported for calendar years (see www.fhwa.dot.gov/policy/ohpi/hss/index.htm). Because FHWA does not actually specify the accounting period for each statistic, it is not possible to put all of the data on a calendar-year basis. However, *A Guide to Reporting Highway Statistics* (2005) does instruct reporting agencies to report expenditure data and receipts data for the same accounting period, which means that our comparison of expenditures (in this report) with receipts (Report #17) is internally consistent.

[a] Includes: the acquisition of right of way, including the purchase of land and the cost of moving buildings; preliminary construction and engineering; highway construction, including reconstruction, resurfacing, restoration, rehabilitation, sewer and drainage systems, walls along roads and dams, ferries and landings, utility relocation, and "environmentally related improvements"; and traffic-service facilities. It is not clear if the control of erosion caused by highways is included.

As discussed in the text, these FWHA estimates of capital outlays include some contribution from the private sector. We deduct our estimate of this private contribution in Table 7-4, in order to be left with public-sector expenditures only.

According to the FHWA, "expenditures for indirect street functions, such as sidewalks, street lighting, storm sewers and drainage, are not normally included on form FHWA-536 [the local highway finance report]. Indirect street functions are reported when their costs are an integral part of road and street construction projects" (p. 10-1, FHWA's *A Guide to Reporting Highway Statistics*, 1990). However, highway lighting is included as a State expense (p. 8-9).

Expenditures of Interstate Highway Substitute Funds are included as a line item on form FHWA-531 (State Highway Income), and undoubtedly are included under highway expenditures, if they are made for highways. Expenditures for mass-transit facilities are not included. However, some road expenditures that probably should be attributed to bicycles may be included. I have made an minor, ad-hoc adjustment for this in the final figures presented Table 7-23.

As discussed in the text, the annual capital expenditure per se is not part of the total annualized cost estimated in Table 7-4, but rather is used in the estimate of the annualized cost of the entire highway capital stock (equation 7-7). Hence, the weight, shown at the bottom of the column, is zero.

[b] Maintenance and service. Includes: maintenance of roads and structures; snow removal, sanding, and application of chemicals; traffic control and service facilities, including signs, fences, toll bridges, highway lighting, and litter removal; and toll facility collection costs.

[c] Administration, research, and miscellaneous. Includes: expenses of state transportation departments, and of other state agencies acting on behalf of state transportation departments; highway planning and research; and damages arising from litigation. The distinction between general administrative costs and the cost of administering construction projects is not unambiguous, but FWHA instructs reporting agencies carefully to avoid double counting.

Expenses for energy agencies, air-quality agencies, environmental agencies, and so on, are not included. For example, no EPA or DOE expenditures are included. The administration and research costs of FHWA and NHTSA (the National Highway Traffic Safety Administration) are included, but other administrative expenditures by U. S. DOT are not. (The total federal expenditures on administration and research, shown in the summary Table HF-10 of *Highway Statistics* , is equal to the expenditures by NHTSA and FHWA, shown in Table FA-5.) I estimate these other agency costs in a separate table.

FHWA specifically instructs that "the collection and administrative costs associated with motor-vehicle revenue collections should *not* be included" (*A Guide to Reporting Highway Statistics*, p. 8-10; emphasis in original). As discussed in the text, these collection costs are relevant to our purposes, and thus are estimated and included in Table 7-4.

[d] Includes: traffic supervision, including accident investigation and aid to distressed motorists; highway and traffic safety; driver education; vehicle inspection programs, including motor-vehicle emissions inspections (operated by the state); vehicle size and weight enforcement; and relevant annual capital expenditures (e.g., expenditures for facilities for the highway patrol) (FHWA, *A Guide to Reporting Highway Statistics*, 1990, p. 8-9). Excludes: general policing activities, including investigation of motor-vehicle theft; fire-protection; and presumably, parking enforcement.

Note that I report the FHWA's estimates of police and safety expenditures as a separate item (Table 7-23), rather than as a part of the annualized cost of the highways (Table 7-4). Hence, the weight, shown at the bottom of the column, is zero.

[e] Interest on debt and bond retirements. Includes: interest and redemption costs, costs of preparing and issuing bonds, fiduciary fees, printing fees, and legal opinions. As explained in the text, I count only the portion of these expenditures -- I assume that it is 10% -- that is not included already in the interest component of the annualized capital cost.

[f] The sum of the expenditures in columns b through e, and the total expenditures reported by FHWA in *Highway Statistics*.

[g] The weight is the fraction of the expenditure that is counted in this analysis as a cost of the highway infrastructure. See the notes pertaining to the individual expenditure or cost items.

TABLE 7-4. EXPENDITURES NOT INCLUDED BY FHWA, 1971-2003 (10^6 NOMINAL $)

Year*	Collec. expenses[a]	Leaking tanks[b]	Extra m & r[c]	Emb. private[d]	Land costs not included[e]		Annualized capital cost[f]		Total annualized cost[g]	
					low	*high*	*low*	*high*	*low*	*high*
2003	7,368	171	0	(4,150)	8,385	13,975	112,298	283,326	*168,717*	*339,745*
2002	8,138	169	0	(3,875)	8,181	13,635	109,860	277,176	*163,261*	*330,577*
2001	8,255	165	0	(3,600)	7,916	13,194	106,559	268,848	*158,066*	*320,355*
2000	6,974	163	0	(3,350)	7,359	12,265	99,050	249,903	*147,771*	*298,623*
1999	7,046	162	0	(3,125)	6,867	11,445	92,437	233,217	*139,711*	*280,491*
1998	6,401	156	0	(2,900)	6,277	10,462	84,417	212,983	*128,533*	*257,099*
1997	6,033	38	0	(2,700)	5,803	9,672	78,013	196,826	*119,997*	*238,810*
1996	6,101	0	0	(2,500)	5,617	9,362	75,707	191,007	*116,653*	*231,953*
1995	6,051	145	0	(2,325)	5,172	8,619	69,662	175,756	*109,444*	*215,538*
1994	5,625	141	0	(2,150)	5,085	8,476	68,734	173,415	*107,349*	*212,030*
1993	5,376	138	0	(2,000)	4,743	7,906	64,119	161,772	*101,343*	*198,996*
1992	5,272	135	0	(1,875)	4,597	7,662	62,250	157,056	*98,420*	*193,226*
1991	4,625	131	0	(1,750)	4,397	7,328	59,608	150,391	*93,047*	*183,830*
1990	4,979	100	0	(1,675)	4,218	7,030	57,196	144,305	*89,767*	*176,876*
1989	4,612	134	0	(1,600)	3,977	6,629	53,895	135,977	*83,929*	*166,010*
1988	4,585	132	0	(1,550)	3,946	6,577	53,536	135,071	*82,775*	*164,311*
1987	4,338	130	0	(1,500)	3,681	6,135	49,846	125,760	*77,993*	*153,907*
1986	4,462	0	0	(1,450)	3,501	5,836	47,377	119,531	*74,727*	*146,882*
1985	4,005	0	0	(1,375)	3,190	5,317	43,070	108,664	*68,336*	*133,931*
1984	3,506	0	0	(1,300)	2,769	4,616	37,211	93,883	*59,673*	*116,345*
1983	3,232	0	0	(1,225)	2,423	4,039	32,410	81,770	*53,588*	*102,948*
1982	2,906	0	0	(1,150)	2,282	3,804	30,529	77,023	*50,283*	*96,777*
1981	2,662	0	0	(1,050)	2,364	3,940	31,865	80,394	*50,443*	*98,973*
1980	2,468	0	0	(950)	2,437	4,061	33,069	83,433	*50,328*	*100,693*
1979	2,190	0	0	(800)	2,108	3,513	28,648	72,277	*44,451*	*88,081*
1978	2,059	0	0	(625)	1,789	2,982	24,407	61,578	*39,125*	*76,296*
1977	1,906	0	0	(450)	1,567	2,612	21,545	54,358	*34,712*	*67,525*
1976	1,717	0	0	(250)	1,667	2,779	23,310	58,811	*35,312*	*70,812*
1975	1,696	0	0	(250)	1,725	2,876	24,139	60,901	*35,390*	*72,153*
1974	1,498	0	0	(250)	1,571	2,619	21,945	55,367	*32,128*	*65,550*
1973	1,329	0	0	(250)	1,459	2,431	20,344	51,327	*29,577*	*60,561*
1972	1,152	0	0	(250)	1,472	2,454	20,534	51,806	*28,937*	*60,210*
1971	1,179	0	0	(250)	1,476	2,460	20,587	51,940	*28,522*	*59,875*
wt[h]	*1.0*	*1.0*	*1.0*	*1.0*	*0.0*	*0.0*	*1.0*	*1.0*	**n.a**	**n.a.**

* See note to Table 7-3, which is pertinent to the use of FHWA statistics in this table.

[a] As explained in the text, the FWHA excludes from its expenditure estimates states' costs of collecting and administering highway-user fees. I have added these back in, along with my estimate of collection costs incurred by federal and local governments and by states for collecting non-user revenues for highways.

[b] Leaking underground storage tanks. As explained in the text, the FWHA does not include revenues to and expenditures from the leaking-underground-storage-tank (LUST) trust fund, perhaps because they are not a cost of highway use per se, but rather a cost associated with using certain kinds of highway fuels. In any event, the cost of the LUST program certainly is attributable largely to transportation fuels and hence to motor-vehicle use, if not to highways per se. As I am concerned with the cost of motor-vehicle use in general, and not just the cost of highways, I have included this cost here.

[c] Extra maintenance and repair costs required to prevent deterioration of the infrastructure. As discussed in the text, if the highway system is deteriorating, then present maintenance and repair costs might underestimate *future* costs. However, because ours is an analysis of historical costs, not a prediction of future costs, we do not count this cost.

[d] This is our estimate of the private-sector contribution to highway financing as embedded in the FHWA's estimate of capital outlays in column *a* of Table 7-3. As discussed in the text, FHWA asks the state and local agencies that provide financial statistics to estimate the amount of private investment in highways, and then reports the total amount as part of capital outlays for the highways. Because we classify all private investment in the highways as a "motor vehicle good or service bundled in the private sector" (Report #6 in the Social-Cost series), we must deduct the embedded estimates of private investment from the FHWA's reported capital outlays, in order to be left with *public-sector* capital outlays for highways. Hence, the values shown here are negative. On the basis of the estimates by Hu et al. (1989), I have made up the historical series shown here.

As discussed in the text, the annual private capital investment per se is not part of the total annualized cost estimate, but rather is used in the estimate of the annualized cost of the entire highway capital stock (equation 7-7), and is included in the "annualized capital cost" column of this table. Hence, the weight, shown at the bottom of the column, is zero.

[e] My estimate of land costs not included in annual capital expenditures reported by State DOTs (see section 7.2.7). These costs are shown here for information only; they are not used *as such* in our estimates of the total annualized cost of the highways (hence the weight of zero for this column). (As shown in equation 7-7, the true land cost is properly accounted for in a different manner.)

[f] The annualized replacement cost of the entire highway capital stock, including all land. See equation 7-7. Includes the private capital investment shown in this table, as well as the FHWA-reported capital expenditure in Table 7-3.

[g] The sum of current expenditures in all columns of Tables 7-3 and 7-4, each multiplied by the weights shown at the bottom of the column. In the final analysis (but not in this table), current expenditures are converted to 1991$ using GNP price deflators. The totals shown here do not include the tiny deduction for expenditures on bicycle projects. See the discussion in the text.

[h] The weight is the fraction of the expenditure that is counted in this analysis as a cost of the highway infrastructure. See the notes pertaining to the individual expenditure or cost items.

TABLE 7-5. ESTIMATION OF THE VALUE OF LAND IN THE RIGHT-OF-WAY FOR PUBLIC ROADS IN THE U. S., 1991

	Road area (mi^2)[a]		Extra ROW (factor)[b]		Price of land ($/acre)[c]		Value of land ($10^9$$)[d]	
	P	U	P	U	P	U	P	U
Urban								
Interstate freeway	231	0	1.2	1.2	60,000	42,000	10.6	0.0
Other freeway	123	0	1.2	1.2	60,000	42,000	5.7	0.0
Principal Arterial	533	0	1.2	1.2	75,000	52,500	30.7	0.0
Minor Arterial	548	3	1.2	1.2	80,000	56,000	33.6	0.1
Collector	459	5	1.2	1.2	105,000	73,500	37.0	0.3
Local road	2,573	179	1.2	1.2	105,000	73,500	207.5	10.1
Subtotal urban	*4,467*	*187*	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*325.2*	*10.5*
Rural								
Interstate freeway	533	0	1.25	1.25	840	600	0.4	0.0
Other arterial	976	0	1.25	1.25	1,120	800	0.9	0.0
Minor Arterial	1,053	0	1.25	1.25	1,680	1,200	1.4	0.0
Major collector	2,353	291	1.25	1.25	2,520	1,800	4.7	0.4
Minor collector	936	465	1.25	1.25	3,360	2,400	2.5	0.9
Local road	2,865	5,674	1.25	1.25	6,720	4,800	15.4	21.8
Subtotal rural	*8,716*	*6,431*	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*25.3*	*23.1*
Urban + rural	**13,183**	**6,619**	n.a.	n.a.	*n.a.*	*n.a.*	**350.5**	**33.6**

P = paved roads; U = unpaved roads; n. a. = not applicable.

[a]The area of the roadbed and shoulder for public roads (Table 6-A.1, Report #6). Does not include unused right-of-way. Excludes area devoted to private roads.

[b]A factor to account for additional right-of-way (ROW), expressed as: the ratio of the total area of the right-of-way (roadway+shoulder+unused right-of-way) to the area of the roadbed and shoulder. These are my estimates.

[c]These are my estimates, made on the basis of the following data:

Low-end value, rural farm land: The National Agricultural Statistics Service (NASS, 2003) reports the results of an annual comprehensive survey of farm real estate prices throughout the U. S. The estimates of real estate value include the value of all land and buildings. In 1991 the average U. S. farm real estate value was $700/acre (NASS, 2003, p. 3). (By 2002, the average had risen to $1,200/acre.) Values are highest in the Northeast (more than twice the national average in 2002) and lowest in the Rocky-Mountain and Great Plains regions (less than half the national average in 2002). Cropland values are about three times pasture land values. (Previously the Economic Research Service [1993] reported an average value of farmland of $572/acre in 1991, but this apparently has been revised.) Presumably the value of structures is a very minor fraction of the total value of farmland.

I use the average farmland real estate value as a starting point in my estimates of land prices under roadways. I assume that in principle the only type of road that displaces *only* farmland is an unpaved rural interstate freeway. (I say "in principle" because there are no unpaved interstate freeways.) I then assume that as one goes from the "interstate" to the "local" road category less farmland and more developable land is displaced, and hence that the average land price increases. I also assume that paved roads displace more developable land than do unpaved roads.

My estimates of how land prices increase as one moves from 100% farmland to, say, rural residential land, and from rural land values to urban-area land values, are informed by Gwartney (2004), who reports land values in the U. S. *relative* to those for general farming in rural areas:

- intense farming in developing areas: 3.0
- undeveloped rural acreage distant from suburban areas: 10
- undeveloped rural acreage close to major cities: 20
- inferior residential land in rural areas: 25
- standard residential land in suburban areas: 75
- prime residential land in major cities: 150 +
- standard commercial land in suburban areas: 200
- downtown commercial land in suburban areas: 500
- central business area commercial land in major cities: 2000 +

High-end values, land in suburbs and central cities. The foregoing suggests that land in suburban areas taken up by roads would be worth from $50,000 to $300,000/acre, and that land under roadways in and around major cities would be worth from $100,000 to over $2 million per acre. Other data support the lower end of these ranges. In Report #6, I use data from the Bureau of the Census, *Characteristics of New Housing: 1991* (1992) to estimate that in 1991, the average value of improved land for new one-family houses was $113,000/acre. The value of the unimproved land probably was less than $100,000/acre. Similarly, the Society of Industrial and Office Realtors (1993) reports that unimproved industrial land in suburbs and central cities typically costs $0.50 to $3.00/ft^2, or about $20,000 to $130,000/acre.

Of course, in reality the value of land is determined partly by the accessibility provided by the roads implicitly assumed away in this calculation. Recall, however, that I have framed the whole social-cost analysis under the assumption that the benefits provided by motor-vehicle use remain constant.

[d]Equal to the area multiplied by the additional right-of-way factor multiplied by the price multiplied by 640 acres/mi^2.

TABLE 7-6. MILES, COST PER MILE, AND TOTAL COST OF ROADS, 1991

	Roads in place in 1991[a]	Highway capital improvements in 1991[b]		Capital cost per mile[c]	Total in-place cost[d]
Urban	10^3 miles	miles	10^6 $	10^6 $/mi	(billion $)
Interstate freeway	11.6	745	2,777	3.73	43.2
Other freeway	7.7	179	512	2.86	22.1
Principal Arterial	52.3	677	1,403	2.07	108.5
Minor Arterial	74.5	502	652	1.30	96.8
Collector	76.3	322	349	1.08	82.6
Local road	491.9	123	152	1.24	608.4
Subtotal urban	*714.4*	*2,548*	*5,846*	*2.29*	*961.6*
Rural					
Interstate freeway	33.7	1,658	1,360	0.82	27.6
Other arterial	85.7	2,460	1,563	0.64	54.5
Minor Arterial	142.9	1,412	642	0.45	65.0
Major collector	388.6	2,512	663	0.26	102.6
Minor collector	196.0	414	87	0.21	41.2
Local road	720.2	337	139	0.41	297.1
Subtotal rural	*1,567.1*	*8,793*	*4,454*	*0.51*	*588.0*
Total urban + rural	**2,281.5**	**11,341**	**10,300**	**0.91**	**1,549.6**

[a]From FHWA (1992).

[b]The FWHA (1992) shows the number of miles and "total cost" of highway capital improvement projects initially authorized in fiscal year 1991, by type of capital improvement (new construction, relocation, reconstruction, major widening, minor widening, and rehabilitation, and resurfacing) and type of road (the same road-type categories used in this table). In each category of road, I have added up the total cost and total miles of all seven types of capital improvements. Note that what is counted as a capital improvement here (new construction, relocation, etc.) is the same as what is counted as a capital expenditure in Table 7-3.

The FHWA estimates of "total cost" apparently include state and local costs as well as federal costs.

[c]Million dollars spent on capital improvement divided by miles of roadway improved, in 1991.

[d]Miles of road in place multiplied by the capital cost per mile.

TABLE 7-7. COMPARISON OF CENSUS WITH STATE ESTIMATES OF PARKING REVENUES IN CALIFORNIA AND NEW YORK , FY 1991 (10^9 $)

	New York		California	
	State data	U. S. Census	State data	U. S. Census
New York city (NYC) meters, garages	0.053[a]	0.053[b]	not applicable	not applicable
All city meters and garages except NYC	0.042[c]	0.049[d]	0.135[e]	0.140[f]
County meters, garages	Included with cities		not estimated	0.032[f]
Leased garages	not included	not included	not included	not included
Local parking tax	included above	not included	not included	not included
Total	*0.095[g]*	*0.102[h]*	*not estimated*	*0.172[h]*

[a]In fiscal year 1991, the five boroughs of New York received $0.053 billion from city-owned-and-operated parking meters and garages (City of New York, 1992; Office of the Comptroller, City of New York, 1993). This figure includes local taxes, such as parking taxes, but not state-level taxes, such as sales taxes. (New York City received $0.059 billion from parking meters in fiscal year 1992; City of New York, 1992). Also, it does not include revenues from garages leased by the city to private operators.

[b]From the Bureau of the Census, *City Government Finances: 1990-91* (1993). The Census estimates do not include revenues from garages leased by the city to private operators, or any local or state taxes. Note that the state estimate includes local parking taxes, but the Census estimate does not.

[c]In fiscal year 1991, all counties, towns, villages and cities except New York City in New York state received $0.0417 billion (Madej, 1993) in revenues from parking charges. This figure includes local taxes, such as parking taxes, but not state-level taxes, such as sales taxes. Also, it does not include revenues from garages leased by the city to private operators, or garages owned but not run by the city.

In New York state, most local governments place revenue from parking meters, garages, and lots into a general fund. However, a few of the larger cities do use the revenues to cover expenditures for the parking operations; in fiscal year 1991, $16 million out of the total $41.7 million in parking revenues received in the State (excluding New York City) were put into "Enterprise Fund" accounts, to cover the costs of the parking operation (Madej, 1993).

[d]Equal to the total of $0.102 billion less the $0.053 billion received by New York City. Note that the state estimate includes local parking taxes, but the Census estimate does not.

[e]In fiscal year 1991, cities in California received $0.135 billion in revenues from parking facilities (California State Controller, 1992), including revenue from on -street parking meters, but excluding revenues from facilities leased from the city. The amounts shown also exclude local parking taxes, which in California are reported as “other nonproperty taxes”.

[f]In fiscal year 1991, cities in California of 300,000 or more persons received $0.084 billion in parking charges (Bureau of the Census, *City Government Finances: 1990-91*, 1993), and counties of 500,000 or more persons received $0.02 billion in parking charges (Bureau of the Census, *County Government Finances: 1990-91*, 1993). All cities and counties received $0.172 billion (*Government Finances:1990-91 (Preliminary)*, 1993). To scale the estimate for cities of 300,000+ to an estimate for cities of all sizes, and the estimate for counties of 500,000+ to an estimate for counties of all sizes, I multiplied the $0.084 and the $0.02 each by the ratio of: 0.172/(0.084+0.020).

[g]Equal to the sum of the revenues received in New York city and the revenues received in all other cities, towns, villages, and counties.

[h]The Census reports total parking-charge receipts of $0.102 billion for the whole of New York State, and receipts of $0.172 billion for the whole of California State (*Government Finances:1990-91 (Preliminary)*, 1993).

TABLE 7-8. ESTIMATE OF THE COST OF INSTITUTIONAL PARKING, 1991 (10^9 $, EXCEPT AS NOTED)

1. Parking revenues received by universities, airports, and hospitals (local taxes excluded)[a]	2.51
2. Parking revenues received by sports facilities[b]	0.09
3. Estimated producer surplus (fraction)[c]	0.00
4. Estimated cost of priced private nonresidential offstreet parking[d]	*2.6*

[a]From the IMPC (1992). The estimate is equal to total revenues, including parking taxes, as estimated in Table 7-9, divided by one plus the tax rate (7.1% ti 7.6%, calculated in Table 6-B.4 of report #6). I divide by the tax rate in order to obtain revenues excluding parking taxes.

[b]The BEA's benchmark Input-Output Tables for 1982 show the following PCEs (personal-consumption expenditures) for parking: parking lots and garages, $1.490 billion (includes $0.0407 billion in sales taxes); private auto parking (in public parks, like Yosemite): $0.083 billion; baseball games: $0.0155 million; football games: $0.0097; other professional sporting events, $0.010 billion; universities $0.0102 billion (Key, 1993), for a total of $1.62 billion. (The BEA's estimates of payments for parking apparently exclude payments at airports and hospitals.)

Note that the BEA estimate is consistent with $1.67 billion in parking fees (including taxes) that households reported paying in 1984 (Division of Consumer Expenditure Surveys, 1993), but is lower than the revenues reported by facilities. I believe that this means that households under-report expenditures for parking, and that the PCEs are too low. However, I can use them to scale up the reported revenues: PCEs on parking at sporting facilities are 2.7% of PCEs on parking at parking lots and garages. Applying this percentage to the $3.3 billion in revenues to commercial parking operators in 1991 results in an estimate of $0.09 billion in parking revenues to sporting facilities in 1991.

[c]My assumption.

[d]Equal to (line 1 + line 2) × (1.0 − line 3).

TABLE 7-9. PARKING REVENUES RECEIVED BY UNIVERSITIES, AIRPORTS, AND HOSPITALS

	Number of institutions in IMPC (1992)[a]	Institutions in IMPC divided by total institutions[b]	Estimated number of institutions in U. S.[c]	Parking revenue reported by IMPC (1992) (10^3 $)[d]	Estimated parking revenue in U.S. (10^3 $)[e]
Universities					
Small	13	0.03	433	7,071	235,700
Medium	52	0.40	130	52,523	131,307
Large/extra large	71	0.70	101	232,972	332,817
Subtotal universities	*136*	*0.20*	*665*	*292,566*	*699,824*
Airports					
Small/non-hub	10	0.05	200	45,591	911,820
Medium	16	0.30	53	93,885	312,948
Large	15	0.90	17	320,408	356,009
Subtotal airports	*41*	*0.15*	*270*	*459,884*	*1,580,777*
Hospitals					
Small	4	0.02	200	4,665	233,250
Medium	4	0.15	27	1,447	9,647
Large/extra large	19	0.30	63	52,265	174,217
Subtotal hospitals	*27*	*0.09*	*290*	*58,377*	*417,113*
GRAND TOTAL				**810,826**	**2,697,714**

Note: totals might not equal sum of components as shown, because of rounding.

[a]As reported in the IMPC, *Who's Who in Parking, The Annual Membership Directory and Data Book* (IMPC, 1992). This book compiles data voluntarily reported by IMPC members. The book includes data from owners who lease their facilities to somebody else for operation. Although some of the IMPC institutions are owned privately (e.g., private hospitals and colleges), and some are owned by the public sector (e.g., airports, public hospitals, and public universities), the IMPC considers that all of its members are in the “public” parking industry (IMPC, 1993).

[b]The IMPC’s estimate.

[c]Equal to the number of institutions in the IMPC database divided by the fraction of the third column.

[d]Our summary of the data provided by in the IMPC's *Who's Who in Parking, The Annual Membership Directory and Data Book* (1992). Revenues include local parking taxes (Whitmer, 1993).

[e]Parking revenue reported by the IMPC (1992) divided by the fraction in column 3. Includes local parking taxes.

TABLE 7-10. CRIMES RELATED TO MOTOR-VEHICLE USE, 1991

Type of crime	Persons arrested	Offenses reported	Fraction for which no substitutes		% not in FHWA
			Low	*High*	
Murder of police during traffic stop	13	13	0.30	0.70	25%
Murder during motor-vehicle theft	79	81	0.50	0.90	100%
Murder during robbery of gas station	86	89	0.25	0.50	100%
Rape in parking lot or garage	1,685	4,477	0.10	0.25	100%
Robbery of gas station	4,506	17,829	0.20	0.50	100%
Robbery in parking lot or garage	20,685	81,840	0.05	0.20	100%
Robbery of motor vehicles ("carjackings")	4,805	19,012	0.50	0.80	100%
Theft of automobiles and motorcycles	171,353	1,370,934	0.50	0.80	100%
Theft of trucks and buses	30,532	244,275	0.50	0.80	100%
Larceny theft from motor vehicles	356,491	1,827,508	0.20	0.50	100%
Larceny theft of motor-vehicle accessories	224,416	1,150,443	0.50	0.80	100%
Arson to motor-vehicles	2,472	25,386	0.50	0.80	100%
Arson to gas stations and car dealerships	50	303	0.20	0.50	100%
Driving under the influence	1,771,400	n.e.	1.00	1.00	5%
Hit and run	55,245	n.e.	1.00	1.00	90%
Other traffic crimes	458,167	n.e.	1.00	1.00	5%
Fraud, receiving stolen property, and others	30590	n.e.	0.50	0.90	100%

n.e. = not estimated. All data and estimates are discussed in the text.

TABLE 7-11. ESTIMATION OF THE PERCENTAGE OF CRIMES, IN GENERAL CRIME CATEGORIES, THAT WOULD NOT OCCUR WERE THERE NO MOTOR-VEHICLE USE, 1991

Crime	Persons arrested	Total offenses	Nominal MV-related fraction[b]		MV- related percentage[c]	
	1991[a]	*1991[a]*	*Arrests*	*Offenses*	*Low (arrests)*	*High (offenses)*
Homicide	24,050	24,703	0.007	0.007	0.003	0.005
Rape	40,120	106,593	0.042	0.042	0.004	0.011
Robbery	173820	687,732	0.173	0.173	0.025	0.059
Motor-vehicle theft	207,700	1,661,738	0.972	0.972	0.486	0.778
Larceny theft	1,588,300	8,142,228	0.366	0.366	0.116	0.225
Arson	20,000	99,784	0.126	0.257	0.062	0.205
Driving under the influence	1,771,400	n.e.	1.000	n.e.	1.000	n.e.
Hit and run	55,245	n.e.	1.000	n.e.	1.000	n.e.
Other traffic crimes	458,167	n.e.	1.000	n.e.	1.000	n.e.
Fraud, receiving stolen property, other potentially involving motor-vehicle use	611,800	n.e.	0.050	n.e.	0.025	n.e.

MV = motor vehicle

[a]From the FBI (1992a). See also Table 7-10.

[b]Equal to total motor-vehicle-related arrests or offenses in each crime category (Table 7-10) divided by total arrests or offenses (this table).

[c]See equation 7-12.

TABLE 7-12. FIRE-PROTECTION EXPENDITURES ALLOCATED TO MOTOR-VEHICLE USE, 1990

Code[a]	Type of fixed property[a]	Fires	Civ. inj.	Fatalities		Loss
				firemen	civilian	(10^6 $)
173	Bus passenger terminals	49	1	0	0	0.0
57 pt.[b]	Motor vehicle sales and service	8,129	164	0	4	71.7
767	Refinery and NG plant	146	4	0	3	7.6
784, 780 pt.	Car assembly and manufacture	643	20	0	0	6.4
841, 840 pt.	Flammable liquids	279	10	0	2	37.5
880 pt.	Vehicle storage insufficient information (m. v. share)	751	9	0	0	10.6
881	Residential parking garage	10,470	171	1	10	50.7
882	General vehicle parking garage	1,550	25	0	2	11.2
883	Bus, truck, auto fleet, automobile dealer storage	505	8	0	0	8.3
920 pt.	Special structures insufficient information (m. v. share)	32	0	0	0	0.1
921	Bridges	539	3	0	1	1.9
922	Tunnels	85	4	0	0	0.0
924	Toll stations	24	0	0	0	0.0
96	Road property[c]	273,478	1,344	4	352	376.0
n.a.	All fires	940,107	15,682	22	2,547	4,260.9
n.a.	*All coded fires*[d]	*874,489*	*15,420*	*22*	*2,505*	*4,175.3*
Motor-vehicle related coded fires						0.0
	Total[e]	296,520	1,759	5	371	571.5
	Fraction of all coded fires[f]	*0.34*	*0.11*	*0.23*	*0.15*	*0.14*

civ. inj. = civilian injuries; pt = part; m. v. = motor vehicle; n.a. = not applicable. Data from the NFIRS, Report Tally 22, for 1990 (U. S. Fire Administration, 1992), except as calculated here.

[a]Fixed property types are described by the National Fire Information Council (1989). The codes that end in zero -- 780, 840, 880, 920 -- refer to fires that were classified in a general category, such as vehicle storage, but for which there was insufficient information for further

classification within the general category. I have allocated the data pertaining to such fires to the specific codes within the general category.

[b]Excludes code 576, boat and pleasure craft sales, and code 577, marine service stations.

[c]Vehicle fires and structure fires on freeways, paved public roads, paved private roads, unpaved roads and paths, and uncovered parking areas.

[d]Some of the reported fires were not assigned a fixed-property code. For the purpose of determining the motor-vehicle related fraction of all fires, I exclude these from the total.

[e]Equal to $\sum_{P} D_P \cdot MVF_P$, where D_P is the data (fires, injuries, fatalities, or property loss) for fixed-property-type P, as shown in this table, and MVF_P is the motor-vehicle related fraction of all fires of type P. MVP_P =1.0 for all P codes except 767 (Refinery and NG plants) and 841 (and 840 pt) (flammable liquids.)

I estimate MVF_{767} = 0.10, as follows: First, I assume that most (say, 70%) of the fires are at oil refineries, not natural-gas plants. Then, I assume that 70% of the reported refinery fires are handled by industrial brigades, whose cost presumably is included in the refiners' selling price. This leaves 30% for public fire departments. Finally, I assume that 50% of the public fire-fighting cost of refinery fires can be attributed to motor-vehicle use, because motor-fuel is roughly 50% of the output of refineries in the U. S. The result is that the motor-vehicle related public-fire-fighting share is about 10% of the total.

I estimate MVF_{841} = 0.90, because most stored petroleum liquid is motor fuel.

The total shown does not include outdoor fires, such as brush fires, ignited by motor vehicles, which we were not able to classify separately. On the basis of his familiarity with fire statistics, Ottoson (1992) of the U. S. Fire Administration estimates that there were at least 4,000 fires ignited by motor vehicles. This is a relatively small amount. Moreover, these fires probably cause relatively little loss of property. .

[f]Equal to total motor-vehicle related fires, injuries, fatalities, or property loss divided by all coded fires, injuries, fatalities, or property loss.

TABLE 7-13. REPORTED FIRES BY TYPE OF MOBILE VEHICLE INVOLVED, 1990

#	Type of mobile property[a]	Fires	Civ. inj.	Fatalities		Loss
				firemen	civilian	(10^6 $)
	Passenger road transport					
10	Passenger road transport, unclassified	941	5	0	0	2.2
11	Automobile	170,062	1,143	2	294	350.0
12	Bus, trackless trolley	1,291	8	0	0	9.4
13	Terrain vehicles	1,968	40	0	3	3.3
14	Motor home	1,861	88	0	16	14.5
15	Travel trailer	969	51	0	8	3.8
16	Camping trailer	283	10	0	1	0.6
17	Mobile home/building	10,408	422	0	173	90.0
19	Passenger road transport, other	631	18	0	6	2.4
	Subtotal passenger road transport	*188,414*	*1,785*	*2*	*501*	*476.2*
	Freight road transport					
20	Freight road transport, unclassified	1,308	0	0	4	6.7
21	General use truck, over 1 ton	5,767	73	1	16	24.2
22	General use truck, under 1 ton	14,146	157	1	39	36.2
23	Semi-trailer truck	2,497	37	0	14	23.1
24	Tank truck -- nonflammable cargo	96	4	0	2	0.6
25	Tank truck -- flammable liquids	245	16	0	5	3.7
26	Tank truck -- compressed gas	87	2	0	0	0.4
27	Trash truck	1,032	10	0	0	4.1
28	?[b]	1	0	0	0	0.0
29	Freight road transport, other	189	2	0	1	1.6
	Subtotal freight road transport	*25368*	*301*	*2*	*81*	*100.6*

= mobile property type code; civ. inj. = civilian injuries. Data from the NFIRS, Report Tally 22, for 1990 (U. S. Fire Administration, 1992).

[a]Mobile property types are described by the National Fire Information Council (1989).

[b]Blank line in the NFIRS for 1990.

TABLE 7-14. JUDICIAL AND LEGAL-SYSTEM EXPENDITURES ALLOCATED TO MOTOR-VEHICLE USE

A. THE FEDERAL JUDICIAL SYSTEM

	% of cases[a] in:		Time/ case[b]	Cost[c] (10^9 $)		M. V. share of cases[d]		M. V.-related cost[e] (10^9 $)	
	all court	*sublevel*	*min.*	*low*	*high*	*low*	*high*	*low*	*high*
1. U. S. District courts, civil cases commenced									
Personal injury, product liability -- motor vehicle		0.2%	1	0.01	0.01	100%	100%	0.01	0.01
Personal injury, other -- motor vehicle		2.5%	1	0.06	0.07	100%	100%	0.06	0.07
Insurance and miscellaneous contract actions		11.5%	1	0.27	0.32	3%	5%	0.01	0.02
All other cases		85.8%	1	2.02	2.35	1%	2%	0.02	0.05
All civil cases commenced	*72.0%*	*100%*	*1*	*2.36*	*2.74*	*4%*	*6%*	*0.09*	*0.14*
2. U. S. District courts, criminal cases commenced									
Auto theft		0.4%	2	0.00	0.01	49%	78%	0.00	0.00
Drunk driving/traffic		14.4%	2	0.14	0.16	100%	100%	0.14	0.16
All other cases		85.2%	2	0.83	0.97	1%	2%	0.01	0.02
All criminal cases commenced	*14.9%*	*100%*	*2*	*0.98*	*1.14*	*15%*	*19%*	*0.15*	*0.19*
3. U. S. Courts of Appeal, civil cases	9.5%	100%	2	0.62	0.73	4%	6%	0.02	0.04
4. U. S. Courts of Appeal, criminal cases									
Auto theft		0.4%	3	0.00	0.00	49%	78%	0.00	0.00
Drunk driving/traffic		0.2%	3	0.00	0.00	100%	100%	0.00	0.00
All other cases		99.4%	3	0.34	0.40	1%	2%	0.00	0.01
All criminal cases appealed	*3.5%*	*100%*	*3*	*0.35*	*0.40*	*1%*	*3%*	*0.00*	*0.01*
All federal court cases	**100%**	**n.a.**	**1.3**	**4.31**	**5.01**	**6%**	**9%**	**0.27**	**0.37**

Notes: see next page

[a]Calculated from statistics reported by The Administrative Office of the United States Courts (1992), Tables B-7, C-2, and D-2. That report summarizes cases in U. S. Courts of Appeals and U. S. District Courts in Federal fiscal years 1991 and 1992. I have used the statistics for FY 1992 because statistics for the Courts of Appeal are given for that year only.

[b]Estimated on the basis of statistics reported by the California Administrative Office of the Courts,*1986 Municipal Courts' Judicial Weighted Caseload Study*, (1986), and presented in Table 7-15 here. That report estimates the time per filing in California municipal courts in 1986. As explained in the text, I use this information to estimate *relative* time, for the purpose of allocating total expenditures to different types of cases.

[c]The cost for "All federal court cases," shown at the bottom, is the total annualized cost of the Federal judicial and legal system in calendar year 1991, as estimated from the expenditure data shown in Table 7-1 and the assumptions of Table 7-2. (To convert expenditures to costs, I use the method of section 7.1.2.) The total cost at each of the four sublevels (e.g., "All criminal cases appealed") is equal to the sum of costs in the individual case areas thereunder (e.g., "Auto theft"). I allocate costs to each case area in proportion to the amount of time required:

$$C_A = T_A \cdot F_{A,S} \cdot F_{S,T} / T_F \cdot C_F$$

where:

C_A = the dollar cost allocated to each case area (e.g., "Auto theft")

T_A = the time per case area (fourth column of this table)

$F_{A,S}$ = number of cases in area A as a % of the number of cases in sublevel S (third column of this table)

$F_{S,T}$ = number of cases at sublevel S as a % of the total number of federal court cases (second column of this table)

T_F = average time per federal case (bottom of fourth column of this table)

C_F = total annualized cost of the federal judicial and legal system in calendar year 1991 (bottom of fifth column of this table)

[d]Estimated as follows:

i) Case areas, except auto theft, explicitly identified with motor-vehicle use (e.g., drunk driving/traffic): I assume that all cases are related to motor-vehicle use.

ii) Auto theft: The motor-vehicle related shares are from Table 7-11. These shares account for "substitute" crimes; see the discussion pertaining to that table.

iii) Insurance and miscellaneous contract actions: I choose the motor-vehicle share on the basis of the motor-vehicle share of product liability cases, and my judgment.

iv) U. S. Courts of Appeal, civil cases: I assume that the motor-vehicle share of these cases, in Appeals Courts, is equal to the motor-vehicle share of all civil cases commenced.

v) All other case areas: I assume that only a trivial fraction of these is related to motor-vehicle use.

[e]In each individual case area (e.g., auto theft, drunk driving), the motor-vehicle related cost is calculated using equation 7-12. The motor-vehicle-related cost at the sublevel (e.g., all civil cases commenced) is equal to the sum of the motor-vehicle-related costs in the individual case areas thereunder.

B. The State judicial system (based on general-jurisdiction [GD] cases)

	% of cases[a] in:		Time/ case[b]	Cost[c] (10^9 $)		M. V. share of cases[d]		M. V.-related cost[e] (10^9 $)	
	all GD	*sub-level*	*min.*	*low*	*high*	*low*	*high*	*low*	*high*
Traffic[f]	48.0%	100%	1.0	0.51	0.56	100%	100%	0.51	0.56
Juvenile									
Criminal		60.0%	15.0	0.38	0.42	4%	12%	0.01	0.05
Status		11.0%	8.0	0.04	0.04	0%	0%	0.00	0.00
Child Victim		21.0%	8.0	0.07	0.08	0%	0%	0.00	0.00
Other		8.0%	8.0	0.03	0.03	0%	0%	0.00	0.00
All juvenile	*4.0%*	*100%*	*12.2*	*0.52*	*0.57*	*3%*	*9%*	*0.01*	*0.05*
Civil									
Torts		10.0%	8.0	0.29	0.32	5%	10%	0.01	0.03
Contract		14.0%	8.0	0.40	0.44	5%	10%	0.02	0.04
Real Property		9.0%	8.0	0.26	0.28	0%	0%	0.00	0.00
Domestic		33.0%	8.0	0.95	1.04	0%	0%	0.00	0.00
Estate		7.0%	8.0	0.20	0.22	0%	0%	0.00	0.00
Mental Health		1.0%	8.0	0.03	0.03	0%	0%	0.00	0.00
Small Claims		12.0%	5.0	0.22	0.24	5%	10%	0.01	0.02
Civil Appeals		1.0%	8.0	0.03	0.03	5%	10%	0.00	0.00
Other Civil		13.0%	8.0	0.37	0.41	5%	10%	0.02	0.04
All Civil	*34.0%*	*100%*	*7.6*	*2.75*	*3.01*	*2%*	*5%*	*0.06*	*0.14*
Criminal									
Felony		28.0%	35.0	1.45	1.59	4%	12%	0.05	0.19
Misdemeanor		60.0%	10.0	0.89	0.97	4%	12%	0.03	0.11
Other Criminal		12.0%	10.0	0.18	0.19	4%	12%	0.01	0.02
All criminal	*14.0%*	*100%*	*17.0*	*2.52*	*2.76*	*4%*	*13%*	*0.09*	*0.32*
All state court cases	**100%**	**n.a.**	**5.9**	**6.30**	**6.89**	**11%**	**17%**	**0.68**	**1.07**

[a]From the Court Statistics Project (1992).

[b]See note to Part A of this table, and the discussion in the text.

[c]See note to Part A of this table (substitute “state” for “federal”).

[d]Estimated as follows:
i) Traffic: I assume that all cases are related to motor-vehicle use.
ii) All criminal cases: The motor-vehicle related shares are from Table 7-10. These shares account for “substitute” crimes; see the discussion in the text.
iii) Civil cases: I assume that 5-10% of certain civil cases involving contracts, insurance, and the like, are related to motor-vehicle use.

[e]See note to Part A of this table.

[f]Nominally, “traffic” includes moving violations, ordinance violations, miscellaneous traffic violations, and parking violations. However, the Court Statistics Project (1992) makes it clear that the statistics on traffic cases are poor: in 24 states, the traffic data are incomplete (e.g., do not include some moving violation cases); in 14 states, the traffic data are overinclusive (e.g., include some non-traffic misdemeanors); in 17 states, the traffic data are incomplete and overinclusive; and in many states, data on parking cases are unavailable or incomplete (e.g., include only contested cases). Moreover, in many states, parking cases are handled administratively, not by courts.

C. THE LOCAL JUDICIAL SYSTEM (BASED ON LIMITED-JURISDICTION [LD] CASES)

	% of cases[a] in:		Time/ case[b]	Cost[c] (10^9 $)		M. V. share of cases[d]		M. V. cost[e] (10^9 $)	
	all LD	*sub-level*	*min.*	*low*	*high*	*low*	*high*	*low*	*high*
Traffic[f]	74.0%		1.0	2.18	2.45	100%	100%	2.18	2.45
Juvenile									
Criminal		53.0%	15.0	0.23	0.26	4%	12%	0.01	0.03
Status		13.0%	8.0	0.03	0.03	0%	0%	0.00	0.00
Child Victim		26.0%	8.0	0.06	0.07	0%	0%	0.00	0.00
Other		8.0%	8.0	0.02	0.02	0%	0%	0.00	0.00
All Juvenile	*1.0%*	*100%*	*11.7*	*0.34*	*0.39*	*2%*	*9%*	*0.01*	*0.03*
Civil	12.0%	100%	7.6	2.70	3.03	2%	5%	0.06	0.15
Criminal									
DUI		11.0%	35.0	1.47	1.66	100%	100%	1.47	1.66
Misdemeanor		84.0%	10.0	3.22	3.61	4%	12%	0.12	0.42
Other Criminal		5.0%	10.0	0.19	0.22	4%	12%	0.01	0.03
All criminal	*13.0%*	*100%*	*12.8*	*4.88*	*5.48*	*33%*	*43%*	*1.60*	*2.10*
All local court cases	**100%**	**n.a.**	**3.4**	**10.11**	**11.35**	**38%**	**47%**	**3.85**	**4.73**

[a]From the Court Statistics Project (1992).

[b]See note to Part A of this table, and the discussion in the text.

[c]See note to Part A of this table (substitute "local" for "federal").

[d]Estimated as follows:
- i) Traffic and criminal DUI: I assume that all cases are related to motor-vehicle use.
- ii) All criminal cases except DUI: the motor-vehicle related shares are from Table 7-10. These shares account for "substitute" crimes; see the discussion in the text.
- iii) Civil cases: I assume that the motor-vehicle share of civil cases in local (limited-jurisdiction) courts is the same as the estimated motor-vehicle share of civil cases in state (general-jurisdiction) courts, from Part B of this table.

[e]See note to Part A of this table.

[f]See note to Part B of this table.

TABLE 7-15. MINUTES PER FILING IN CALIFORNIA MUNICIPAL COURTS, 1986

	Min[a]	Filings[a]	M/F[b]	M/F relative to:	
				T1	*T2*
Felony	1,265,871	22,858	55.4	22.2	55.8
Misdemeanors except traffic					
group A nontraffic misdemeanors	1,175,749	63,103	18.6	7.5	18.8
group B nontraffic misdemeanors	140,554	21,304	6.6	2.6	6.7
nontraffic infractions	36,719	19,257	1.9	0.8	1.9
All misdemeanors except traffic	*1,353,022*	*103,664*	*13.1*	*5.2*	*13.2*
Traffic and parking					
group C traffic misdemeanors					
group C non-DUI	1,157,886	36,666	31.6	12.7	31.8
group C DUI	174,780	2,726	64.1	25.7	64.6
group D traffic misdemeanors	287,241	82,155	3.5	1.4	3.5
non-parking traffic infractions	515,526	734,355	0.7	0.3	0.7
illegal parking	59,197	1,356,500	0.04	0.0	0.0
T1: All traffic except parking	*2,135,433*	*855,902*	*2.5*	*1.0*	*2.5*
T2: All traffic including parking	*2,194,630*	*2,212,402*	*1.0*	*0.4*	*1.0*
Civil					
small claims	470,448	69,628	6.8	2.7	6.8
civil other than small claims					
unlawful detainer	239,815	25,874	9.3	3.7	9.3
other civil	499,812	48,017	10.4	4.2	10.5
All civil except small claims	*739,627*	*73,891*	*10.0*	*4.0*	*10.1*
All civil including small claims	*1,210,075*	*143,519*	*8.4*	*3.4*	*8.5*

[a]From the California Administrative Office of the Courts (1986); estimates for California municipal courts in 1986.

[b]Minutes per filing.

[c]Minutes per filing in each area divided by minutes per filing for all traffic except parking (T1) or all traffic (T2).

TABLE 7-16. ALLOCATION OF CORRECTIONAL EXPENDITURES TO MOTOR-VEHICLE USE, 1991

	Government's total costs (10⁹ $)[a]		**Alloca-tion to subarea**[b]	**Fraction related to motor-vehicle use**[c]		**Motor-vehicle related cost** (10^9 $)[d]	
	Low	*High*	*fraction*	*Low*	*High*	*Low*	*High*
Federal	2.12	2.32					
Prisons			0.82	0.013	0.021	0.02	0.04
PP&P[e]			0.13	0.024	0.043	0.01	0.01
Other[f]			0.05	0.014	0.024	0.00	0.00
State	20.10	26.99					
Prisons			0.84	0.040	0.058	0.66	1.30
PP&P[e]			0.10	0.029	0.050	0.06	0.13
Other[f]			0.06	0.038	0.056	0.05	0.09
Local	11.17	15.45					
Jails			0.86	0.286	0.303	2.71	3.98
PP&P[e]			0.14	0.286	0.303	0.43	0.63
Other[f]			0.00	0.282	0.298	0.00	0.00
Totals	*33.39*	*44.75*	*n.a.*			*3.93*	*6.18*

[a]Calculated from the expenditure data of Table 7-1, for calendar year 1991, using the method presented in section 7.1.2 for estimating costs from expenditures.

[b]The Bureau of Justice Statistics, *Justice Expenditure and Employment, 1990* (1992) reports federal, state, and local expenditures on institutions, PP&P, and other correctional activities. The fractions shown here are equal to the BJS estimates of expenditures in each subarea (institutions, PP&P, other) divided by total expenditures, at each level of government.

Note that the BJS' estimates of total expenditures on corrections by level of government are very close to the Bureau of the Census estimates: federal, $1.60 billion; state, $15.36 billion ; and local, $8.14 billion, for fiscal year 1990 (cf. Census estimates in Table 7-1). The BJS estimates of expenditures on corrections include costs for all prisons and jails except those tanks and lockups that hold prisoners for less than 48 hours, and so, apparently, do the Bureau of the Census estimates. (The Census actually collects the data for the BJS report.) In any event, I use the BJS' *Justice Expenditure and Employment* data to apportion the Census' *Government Finance* totals, rather than use the BJS data directly, because I use the Census' *Government Finance* estimates throughout this report.

[c]The motor-vehicle-related fractions of inmates in prisons and jails are from Table 7-17. These fractions, and hence the final cost allocations to motor vehicles, account for the possibility that some of the crimes nominally related to motor-vehicle use would incur anyway (but not involve motor vehicles) even if there were no motor vehicles. See Table 7-10 and section 7.4.6 for more discussion.

The motor-vehicle related fractions of state and federal PP&P are the fractions, based on parole populations, from Table 7-18. The motor-vehicle-related fractions for local PP&P are assumed to the be the same as the fractions for local jails (I could not find data on local PP&P).

The fraction of "other" expenditures attributable to motor-vehicle use is assumed to be the same as the cost-weighted motor-vehicle fraction of expenditures on prisons and jails and PP&P combined.

Note that the motor-vehicle-related fraction of inmates in federal prison is much less than the motor-vehicle-related fraction of federal parolees. This probably is because federal motor-vehicle criminals spend relatively little time and prison, but a lot of time on parole.

[d]Calculated for each subarea using equation 7-12, where the annualized cost (AC) is equal to government cost (federal, state, or local) multiplied by the allocation to the subarea (Institutions, PP&P, and other).

[e]Probation, parole, and pardon. I have no data on pardons for motor-vehicle related crimes. However, I expect that pardons in general consume a very small fraction of the total corrections budget, and safely can be ignored.

[f]This category apparently includes governmental administrative expenses related to corrections.

TABLE 7-17. PRISON AND JAIL INMATES, BY TYPE OF OFFENSE

	Jail inmates 1989[a]	Prison inmates 1991		Motor-vehicle related %, net of substitute crimes[d]	
		State[b]	*Federal[c]*	*low*	*high*
Violent Offenses	*14,714*	*323,064*	*9,557*	*0.9%*	*2.2%*
Homicide	1,084	86,480	1,233	0.3%	0.5%
Kidnapping	n. r.	8,092	430	0.0%	0.0%
Rape and other sex offenses	2,530	65,829	726	0.4%	1.1%
Robbery	3,030	102,642	5,158	2.5%	5.9%
Assault	6,429	56,313	1,964	0.0%	0.0%
Other violent	1,641	3,708	46	0.0%	0.0%
Property Offenses	*31,365*	*171,446*	*7,935*	*7.1%*	*12.3%*
Burglary	8,980	86,237	442	0.0%	0.0%
Larceny Theft	10,217	33,265	1,389	11.6%	22.5%
Motor vehicle theft	2,563	15,217	371	48.6%	77.8%
Arson	n. r.	4,652	173	6.2%	20.5%
Fraud	4,872	19,496	5,113	2.5%	2.5%
Stolen property	2,750	9,554	353	0.0%	0.0%
Other property	1,983	3,025	94	0.0%	0.0%
Drug Offenses	*23,928*	*146,803*	*30,470*	*0.0%*	*0.0%*
Possession	12,202	51,925	n. r.	0.0%	0.0%
Trafficking	10,758	91,690	29,989	0.0%	0.0%
Other and unspecified	968	3,188	481	0.0%	0.0%
Public Order Offenses	*46,236*	*46,590*	*8,585*	*43.0%*	*43.0%*
Weapons	2,140	12,595	3,073	0.0%	0.0%
Obstruction of justice	3,263	n. r.	n. r.	0.0%	0.0%
Traffic	6,676	2,315	119	100.0%	100.0%
Driving under the influence	24,465	9,985	n. r.	100.0%	100.0%
Drunkenness/morals	3,265	n. r.	n. r.	0.0%	0.0%
Violation of parole/probation	3,311	n. r.	n. r.	0.0%	0.0%
Other public order	3,116	21,695	5,393	0.0%	0.0%
Other offenses	*1,717*	*2,818*	*442*	*0.0%*	*0.0%*
All offenses	*117,960*	*690,721*	*56,989*	*7.2%*	*8.9%*
Motor-vehicle-related %, low[f]	**28.6%**	**4.0%**	**1.3%**	**n.a.**	**n.a.**
Motor-vehicle-related %, high[f]	**30.3%**	**5.8%**	**2.1%**	**n.a.**	**n.a.**

n. r. = not reported; n. a. = not applicable.

[a]Bureau of Justice Statistics, *Profile of Jail Inmates, 1989* (1991).

[b]State prison population in 1991 (Bureau of Justice Statistics, *Sourcebook of Criminal Justice Statistics -- 1992*, 1993). See also the Bureau of Justice Statistics, *Survey of State Prison Inmates, 1991* (1993).

[c]Federal prison population at the end of 1990/beginning of 1991 (Bureau of Justice Statistics, *Compendium of Federal Justice Statistics, 1990*, 1993).

[d]The non-zero values are from Table 7-11; The zero values are my assumptions. See the discussion in the text.

[e]The primary data sources (see footnote b) did not report the number of state prison inmates convicted of traffic offenses other than drunk driving. However, I can estimate this number on the basis of data pertaining to those convicted of "driving" related offenses, in large urban counties(Bureau of Justice Statistics, *Felony Defendants in Large Urban Counties, 1990*, 1993):

	Sentenced to prison			*Sentenced to jail*			*Sentenced to probation*		
	number	mean months	fraction of man-months	number	mean months	fraction of man-months	number	mean months	fraction of man-months
Public order	790	35		669	7		547	39	
Driving	305	24	0.264	312	8	0.534	141	30*	0.198

* My assumption

These data indicate suggest, that in large urban counties, inmates convicted of driving-related offenses constitute 26% of inmates convicted of any public-order offense. Therefore, in this table, I estimate the number of traffic offenders in prison so that the number of traffic+DUI offenders in state prisons is 26% of the total number of public-order offenders.

[f]See equation 7-20.

TABLE 7-18. STATE AND FEDERAL PAROLEES, BY TYPE OF OFFENSE, 1991

	Man-months on parole, 1991[a]	
	State	*Federal*
Violent Offenses	*433,680*	*32,892*
Homicide	67,760	270
Kidnapping	6,528	1,676
Rape and other sex offenses	74,826	950
Robbery	204,474	27,615
Assault	72,628	1,664
Other violent	7,464	n. r.
Property Offenses	*351,257*	*43,912*
Burglary	180,601	2,978
Larceny Theft	77,298	12,069
Motor vehicle theft	14,976	3,089
Arson	9,698	100
Fraud	40,393	25,676
Stolen property	21,910	n. r.
Other property	6,381	n. r.
Drug Offenses	*218,068*	*74,765*
Possession	52,854	n. r.
Trafficking	139,270	73,073
Other and unspecified	25,944	n. r.
Public Order Offenses	*53,396*	*20,767*
Weapons	27,281	7,068
Obstruction of justice	n. r.	n. r.
Traffic	n. r.	n. r.
Driving under the influence	7,975	n. r.
Drunkenness/morals	n. r.	n. r.
Violation of parole/probation	n. r.	n. r.
Other public order	18,140	n. r.
Other offenses	*15,690*	*1,020*
All offenses	*1,072,091*	*173,356*
Motor-vehicle-related %, low[b]	**4.6%**	**4.2%**
Motor-vehicle-related %, high[b]	**5.3%**	**5.1%**

n. r. = not reported.

[a]Calculated from data on the number of parolees and mean time on parole, by type of offense (Bureau of Justice Statistics, *National Corrections Reporting Program, 1990,* 1993).

[b]See equation 7-22.

TABLE 7-19. MOTOR-VEHICLE-RELATED EXPENDITURES ON POLLUTION ABATEMENT AND REGULATION

A. TOTAL GOVERNMENT EXPENDITURES ON POLLUTION ABATEMENT AND REGULATION, 1991 (10^6 $)

	Total	Air	Water	Solid waste	Other[a]
Total	**39,322**	**1,717**	**24,767**	**12,004**	**834**
Capital expenditures[b]	*11,561*	*183*	*11,378*	*0*	*0*
Publicly owned electric utilities	*247*	183	64	0	0
Public sewers[c]	*11,314*	0	*11,314*	*0*	*0*
Operating and maintenance expenditures	*27,761*	*1,534*	*13,389*	*12,004*	*834*
Abatement & control					
Publicly owned electric utilities	*169*	155	14	0	0
Public sewers[c]	*10,995*	0	10,995	0	0
Other government enterprise[d]	*6*	0	3	1[e]	2[e]
Federal highway erosion abatement	*4*	0	4	0	0
State, local highway erosion abatement	*537*	0	537	0	0
Other federal	*1,904*	253	974	515	162
Other state and local	*11,224*	187	0	10,856	181
Regulation					
Federal	*1,103*	264	380	213	246
State and local	*1,185*	477	381	302	25
R & D[f]					
Federal	*601*	189	86	112	214
State and local	*33*	9	15	5	4

Notes: see next page.

From the BEA's analysis of pollution abatement and control expenditures, 1972-1994 (Vogan, 1996, Tables 11 and 12). The BEA's estimates are based on Bureau of the Census surveys of government finances and new construction put in place, and on BEA's collection of data on government spending on regulation and monitoring. Expenditures are attributable to the sector that performs, rather than pays for, the air or water pollution abatement or the solid waste collection and disposal (Vogan, 1996, p. 63).

[a] According to Vogan (1996), "other" includes government spending for abatement of noise, radiation, and pesticide pollution.

[b] These are the expenditures shown under "government enterprise fixed capital" in Table 12 of Vogan (1996).

[c] Public sewer systems consist of treatment plants, collection systems, interceptor systems, pumping stations, and dry-waste disposal plants. They do not include private septic systems or sewer connections linking household plumbing to streets.

[d] Government enterprises other than sewer systems and public utilities.

[e] Line 10 of Table 11 in Vogan (1996) shows "current account" (i.e., non-capital) expenditures for "government enterprise" in the categories "air," "water," "solid waste," and "other and unallocated." Table 12 in Vogan breaks this general "government enterprise" category into three subcategories: "publically owned electric utilities," "public sewer systems," and "other," but only as regards expenditures on air pollution abatement and water pollution abatement. The government enterprise expenditures for solid waste and "other" are not anywhere disaggregated by type of government enterprise. Therefore, I assume that these current-account government-enterprise expenditures for solid waste and other abatement pertain to "other government enterprises," not to publically owned electric utilities or public sewer systems.

[f] I assume that these are R & D expenditures by state and federal environmental and resource agencies, not energy agencies. (I estimate motor-vehicle-related R&D by government energy agencies separately.)

B. MOTOR-VEHICLE-RELATED SHARES OF TOTAL POLLUTION ABATEMENT AND REGULATION ACTIVITIES

	Air		Water		Solid waste		Other	
	low	*high*	*low*	*high*	*low*	*high*	*low*	*high*
Capital expenditures								
Publicly owned electric utilities[a]	0.03	0.05	0.03	0.05	0.03	0.05	0.03	0.05
Public sewers[b]	0.05	0.10	0.05	0.10	0.05	0.10	0.05	0.10
Operating & maintenance exp.								
Abatement & control								
Publicly owned electric utilities[a]	0.03	0.05	0.03	0.05	0.03	0.05	0.03	0.05
Public sewers[b]	0.05	0.10	0.05	0.10	0.05	0.10	0.05	0.10
Other government enterprise[c]	0.05	0.10	0.05	0.10	0.05	0.10	0.05	0.10
Federal highway erosion abatement[d]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
State, local highway erosion abatement[d]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Other federal[e]	0.40	0.60	0.05	0.10	0.04	0.08	0.05	0.10
Other state and local[e]	0.40	0.60	0.05	0.10	0.04	0.08	0.05	0.10
Regulation[f]								
Federal	0.40	0.60	0.05	0.10	0.04	0.08	0.05	0.10
State and local	0.40	0.60	0.05	0.10	0.04	0.08	0.05	0.10
R & D[f]								
Federal	0.40	0.60	0.05	0.10	0.04	0.08	0.05	0.10
State and local	0.40	0.60	0.05	0.10	0.04	0.08	0.05	0.10

See the discussion in the text. By way of general comparison, an analyst at the U.S. Department of Commerce, estimates that approximately 80% of government expenditures on R & D, and approximately 20% of government expenditures on regulation and monitoring can be attributed to mobile sources (White, 1993).

[a]In Report #10, I estimate that the production and maintenance of motor vehicles, motor fuels, and motor-fuel infrastructure consumes nearly 5% of the entire electricity production of the U.

S. On this basis, it seems reasonable to assume that the motor-vehicle activity fraction relevant to the regulation and control of pollution from publicly owned electric utilities is 3% to 5%.

[b]The activity fractions are based partly on the estimated contribution of motor-vehicle use to the pollutant burden on sewer systems. See the discussion in the text.

[c]I assume the same shares as for public sewers.

[d]I assume that all expenditures related to highway erosion abatement are attributable in the long run to motor-vehicle use.

[e]The activity fractions for expenditures on air pollution are based on the assumed contribution of motor-vehicle use to ambient air-pollution problems. See the discussion in the text. The activity fractions for expenditures on solid waste are based on the assumed contribution of motor-vehicle use to refuse collection and landfilling activities. See the discussion in the text. The activity fractions in the other pollution categories are my assumptions.

[f]The activity fractions for expenditures on air pollution are based on the assumed contribution of motor-vehicle use to ambient air-pollution problems. See the discussion in the text. The activity fractions for expenditures in the other pollution categories are my assumptions.

C. MOTOR-VEHICLE-RELATED COSTS OF POLLUTION ABATEMENT AND REGULATION, 1991 (10^6 $)

	Air		Water		Solid waste		Other		Total	
	low	*high*	*low*	*high*	*low*	*high*	*low*	*high*	*low*	*high*
Total	**566**	**874**	**1,011**	**3,935**	**480**	**960**	**42**	**83**	*2,099*	*5,853*
Annualized capital costs[a]	*10*	*39*	*274*	*2,608*	*0*	*0*	*0*	*0*	*284*	*2,647*
Publicly owned electric utilities	10	39	1	7	0	0	0	0	*11*	*46*
Public sewers	0	0	273	2,601	0	0	0	0	*273*	*2,601*
Operating and maintenance exp.[b]	*556*	*835*	*737*	*1,328*	*480*	*960*	*42*	*83*	*1,815*	*3,206*
Abatement & control										
Publicly owned electric utilities	5	7	0	0	0	0	0	0	*5*	*8*
Public sewers	0	0	168	674	0	0	0	0	*168*	*674*
Other government enterprise	0	0	0	0	0	0	0	0	*0*	*0*
Federal highway erosion abatement	0	0	4	4	0	0	0	0	*4*	*4*
State, local highway erosion abatement	0	0	537	537	0	0	0	0	*537*	*537*
Other federal	101	152	15	60	21	41	8	16	*145*	*269*
Other state and local	75	112	0	0	434	868	9	18	*518*	*999*
Regulation										
Federal	106	158	6	23	9	17	12	25	*132*	*223*
State and local	191	286	6	23	12	24	1	3	*210*	*336*
R & D										
Federal	76	113	1	5	4	9	11	21	*92*	*149*
State and local	4	5	0	1	0	0	0	0	*4*	*7*

[a]All values except for the totals are calculated as: $MVC = \Delta ACM \cdot ACC$, where the annualized capital cost ACC is calculated with equation 7-7 (without the addition of OME), and ΔACM is calculated with equation 7-13f. The totals are simply the sum of the relevant row or column values.

[b]All values except for the totals are calculated as: $MVC = \Delta ACM \cdot OME$, where ΔACM is calculated with equation 7-13f. The totals are simply the sum of the relevant row or column values.

TABLE 7-20. U. S. GOVERNMENT ENERGY APPROPRIATIONS RELATED TO HIGHWAY TRANSPORTATION, FISCAL YEAR 1991

Appropriations category	Money appropriated in FY 1991[a]	Share to highway transport[b]	Money to highway transport in FY 1991
	(10^6 $)	(percent)	($10^6$$)
Interagency NAPAP[c]	25.3	0.16	4.1
Coal liquefaction	42.7	0.75	32.2
Oil	41.8	0.50	20.9
Shale oil	17.2	0.50	8.6
USGS[d] oil programs	26.0	0.50	13.0
Unallocated fossil energy R&D[e]	83.9	0.23	19.6
Biofuels/alcohol	33.1	1.00	33.1
Program support and direction, solar energy program	5.2	0.27	1.4
Transportation end use[f]	83.8	1.00	83.8
Policy & management, conservation program	3.9	0.39	1.5
Total	n.a.	n.a.	218.1

[a]From the EIA (*Federal Energy Subsidies*, 1992). The amounts shown are actual appropriations, not outlays.

[b]These my are estimates, made as follows:

Interagency NAPAP: the ratio of emissions of precursors of acid deposition (nitrogen oxides and sulfur oxides) from highway vehicles to emissions of precursors from all sources, in 1990 (EPA, 1992);

Coal liquefaction: ratio of liquid-fuel energy consumed by highway vehicles to liquid-fuel energy consumed in transportation in 1990 (Davis and Strang, 1993) (assuming that coal-derived liquid fuels are meant to replace transportation fuels)

Oil, shale oil, and USGS oil programs: ratio of energy consumed by highway vehicles to total petroleum energy used in the United States in 1990 (Davis and Strang, 1993);

Unallocated fossil energy R&D: ratio of energy consumed by highway vehicles to total fossil-fuel energy used in the U.S. in 1990 (Davis and Strang, 1993; EIA, *Annual Energy Review 1992*, 1993).

Biofuels/alcohol: my assumption, based on my knowledge of the biofuels research program

Program support and direction, *solar energy program*: ratio of appropriations for biofuels/alcohol to total appropriations for solar energy

Transportation end use: my assumption, based on the discussion in the EIA's *Federal Energy Subsidies* (1992).

Policy & management, *conservation program*: ratio of appropriations for transportation end use to total appropriations

[c]National Acid Precipitation Assessment Program.

[d]United States Geological Survey.

[e]According to the EIA, this is mostly administrative overhead, and capital and operating costs of national laboratories.

[f]A large portion of this is research related to electric vehicles.

TABLE 7-21. YEARLY APPROPRIATIONS FOR THE STRATEGIC PETROLEUM RESERVE

	Reported approp. (10³ nominal $)[a]		**Capital-cost fraction**[b]		**Approp. estimated in this analysis** (10³ 1991$)			
	Storage facilities	Manage-ment[c]			Capital[d]		Operations and management[e]	
FY			*low*	*high*	*low*	*high*	*low*	*High*
2006	149,000	17,000	0.12	0.12	13,475	17,579	145,624	145,624
2005	152,946	16,764	0.12	0.12	14,108	18,514	152,680	152,680
2004	155,044	15,904	0.12	0.12	14,592	19,442	159,194	159,194
2003	157,823	13,909	0.12	0.12	15,157	20,551	165,798	165,798
2002	154009	16,871	0.12	0.12	15,055	20,793	171,466	171,466
2001	156,637	16,000	0.12	0.12	15,594	21,833	178,693	178,693
2000	158,400	16,000	0.12	0.12	16,139	22,652	185,182	185,182
1999	145,100	15,000	0.12	0.12	15,078	21,252	174,154	174,154
1998	191,500	16,000	0.12	0.12	20,171	28,952	232,471	232,471
1997	204,000	16,000	0.12	0.12	21,756	32,015	255,705	255,705
1996	267,273	16,827	0.16	0.16	38,659	58,448	329,851	329,851
1995	226,938	16,780	0.16	0.16	33,460	33,460	191,127	191,127
1994	191,035	15,775	0.12	0.12	21,561	21,561	172,953	172,953
1993	161,940	14,227	0.12	0.12	18,674	18,674	150,617	150,617
1992	171,678	13,384	0.12	0.12	20,254	20,254	161,689	161,689
1991	187,728	12,846	0.12	0.12	22,724	22,724	179,604	179,604
1990	179,530	12,953	0.12	0.12	22,512	22,512	178,627	178,627
1989	160,021	13,400	0.12	0.12	20,837	20,837	167,345	167,345
1988	151,886	12,276	0.12	0.12	20,507	20,507	164,194	164,194
1987	134,021	13,412	0.12	0.12	18,681	18,681	152,570	152,570
1986	106,979	13,518	0.12	0.12	15,299	15,299	128,299	128,299
1985	441,300	17,890	0.50	0.50	269,308	269,308	291,143	291,143
1984	142,357	16,413	0.12	0.12	21,522	21,522	178,507	178,507
1983	222,528	19,590	0.20	0.20	58,205	58,205	258,441	258,441
1982	175,656	20,076	0.30	0.30	72,024	72,024	195,496	195,496
1981	108,168	19,391	0.12	0.12	18,976	18,976	167,504	167,504
1980	0	22,272	0.60	0.60	0	0	35,590	35,590
1979	632,504	18,111	0.60	0.60	660,177	660,177	471,624	471,624
1978	463,933	14,704	0.60	0.60	522,737	522,737	376,104	376,104
1977	0	7,824	0.60	0.60	0	0	15,700	15,700
1976	300,000	13,975	0.60	0.60	383,603	383,603	285,518	285,518
Ave.	**195,159**	**15,648**	**0.27**	**0.27**	**78,092**	**80,745**	**195,918**	**195,918**

approp. = appropriations; FY = fiscal year; ave. = average.

[a]Data through FY 1996 are from the Office of Strategic Petroleum Reserve (1996, 1997). Data from FY 1997 to FY 2006 are from the budget web page of the Office of Fossil Energy (www.fe.doe.gov/aboutus/budget/index.html). FY 2006 is requested amount; FY 1997 through 2005 are appropriations. A separate amount for management is not shown for FY 2000 and 2001, so I estimated these on the basis of reported FY 1999 and 2002.

[b]My estimated capital component of appropriations for "storage facilities." See the discussion in the text.

[c]Appropriations for management. These do not include appropriations to other DOE accounts used to finance aspects of SPR management (Office of Strategic Petroleum Reserve, 1992).

[d]Calculated as:

$$CA_Y = SFA_Y \cdot CCF \cdot (0.75 \cdot GDPD_Y + 0.25 \cdot GDPD_{Y-1})$$

where:

CA_Y = estimated appropriation for capital fiscal year Y
SFA_Y = reported appropriations for storage facilities in fiscal year Y (this table)
CCF = the capital-cost fraction (this table)
$GDPD_Y$ = the ratio of the GDP price deflator for calendar year Y to the GDP price deflator for the base year (1991)
$GDPD_{Y-1}$ = the ratio of the GDP price deflator for calendar year Y-1 to the GDP price deflator for the base year (1991)

The GDP price deflators are weighted this way because the federal fiscal year Y ends September 30 of calendar year Y.

[e]Calculated as:

$$OMA_Y = (SFA_Y \cdot (1 - CCF) + MA_Y) \cdot (0.75 \cdot GNPD_Y + 0.25 \cdot GNPD_{Y-1})$$

where:

OMA_Y = estimated appropriations for operation and management in fiscal year Y
MA_Y = reported appropriations for management in fiscal year Y
other terms as defined in note d.

TABLE 7-22. ALLOCATION OF THE COST OF THE SPR, AND OF DEFENDING MIDDLE-EAST OIL, TO SIX CLASSES OF MOTOR VEHICLES (10^9 1991$)

	Gasoline vehicles			Diesel vehicles			Total
	LDAs	*LDTs*	*HDVs*	*LDAs*	*LDTs*	*HDVs*	
SPR - low	0.027	0.011	0.001	0.000	0.000	0.012	0.052
SPR - high	0.346	0.142	0.017	0.004	0.004	0.151	0.664
Defense - low	0.40	0.16	0.02	0.00	0.01	0.18	0.76
Defense - high	4.43	1.82	0.21	0.05	0.06	1.93	8.50

The total SPR cost related to motor-vehicle use is estimated in this report. The total defense cost related to motor-vehicle use is estimated in Report #15. The total is allocated to the six different vehicle classes according to the estimated distribution of Middle East petroleum across the classes (see Report #10 and Table 10-14).

TABLE 7-23. SUMMARY OF MOTOR-VEHICLE INFRASTRUCTURE AND SERVICES PROVIDED BY THE PUBLIC SECTOR, 1991 AND 2002 (10^9 $)

	10% ΔMVU (1991)		100% ΔMVU (1991)		100% ΔMVU (2002)		
Cost item	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Q*[a]
A1. Direct expenditures (FHWA)[b]							
Annualized cost of highways (FHWA)	9.0	18.5	90.4	184.9	159.9	335.7	A2
Highway law enforcement and safety	0.45	0.70	7.4	8.7	12.6	15.8	A3
A2. Other direct expenditures[c]							
Collection expenses, LUST, extra m&r	0.46	0.46	4.7	4.7	8.3	8.3	A3
Annualized cost of municipal and institutional offstreet parking	n.e.	n.e.	11.9	19.8	17.5	29.0	A2/3
Deduction for embedded private investment in roads	(0.30)	(0.75)	(3.0)	(7.5)	(6.6)	(16.7)	C
B. Indirect expenditures							
Other police-protection costs (not estimatd by FHWA) related to MV use	0.10	0.47	0.8	4.1	1.9	9.3	A2
Fire-protection costs related to MV use	0.07	0.27	0.7	2.8	1.4	5.5	A2
Emergency-service costs of MV accidents included in police and fire costs	(0.15)	(0.16)	(1.1)	(1.1)	(1.4)	(1.4)	A2/B
Judicial and legal-system costs	0.46	0.59	4.8	6.2	8.9	11.6	A2
Legal costs of MV accidents included under judicial and legal-system costs	(0.09)	(0.12)	(0.9)	(0.9)	(1.2)	(1.2)	A2
Jail, prison, probation, and parole costs related to MV use	0.39	0.61	3.9	6.2	7.0	9.4	A2
Regulation and control of air, water and solid-waste pollution related to MV use	0.17	0.56	2.1	5.9	7.1	15.4	A2
Energy and technology R & D	n.e.	n.e.	0.3	0.5	0.3	0.8	A3
MV-related costs of other agencies	n.e.	n.e.	0.1	0.1	0.1	0.1	D
Military expenditures related to the use of Persian-Gulf oil by MVs	n.e.	n.e.	0.8	8.5	0.8	11.2	B, D[d]
Annualized cost of the SPR	0.00	0.06	0.1	0.7	0.0	0.9	A2
Total	n.e.	n.e.	**122.9**	**243.2**	**216.5**	**433.6**	

Notes: see next page

ΔMVU = change in motor-vehicle use; MV = motor vehicle; O & M = operation & management.

[a] Q = Quality of the baseline year-1991 estimate (see Table 1-3 of Report #1).

[b] With minor exceptions, these are based on FHWA estimates of government expenditures for highways. The A1 estimates shown here *exclude* user tax-and-fee collection expenses, LUST-fund costs, and extra maintenance and repair (m&r) costs, but *include* the embedded private-sector investment in roads (Table 7-4), because the FHWA expenditure estimates exclude collection, LUST, and extra m&r costs, but include embedded private costs. In part A2 of this table the excluded collection, LUST, and extra m&r costs are added back in, and the included embedded private costs are deducted.

[c] See note b.

[d] A review and analysis of the literature with a good deal of supposition.

FIGURE 7-1. ESTIMATION OF THE MOTOR-VEHICLE RELATED COST OF GOVERNMENT INFRASTRUCTURE AND SERVICES, AS A FUNCTION OF COST-RELEVANT ACTIVITY

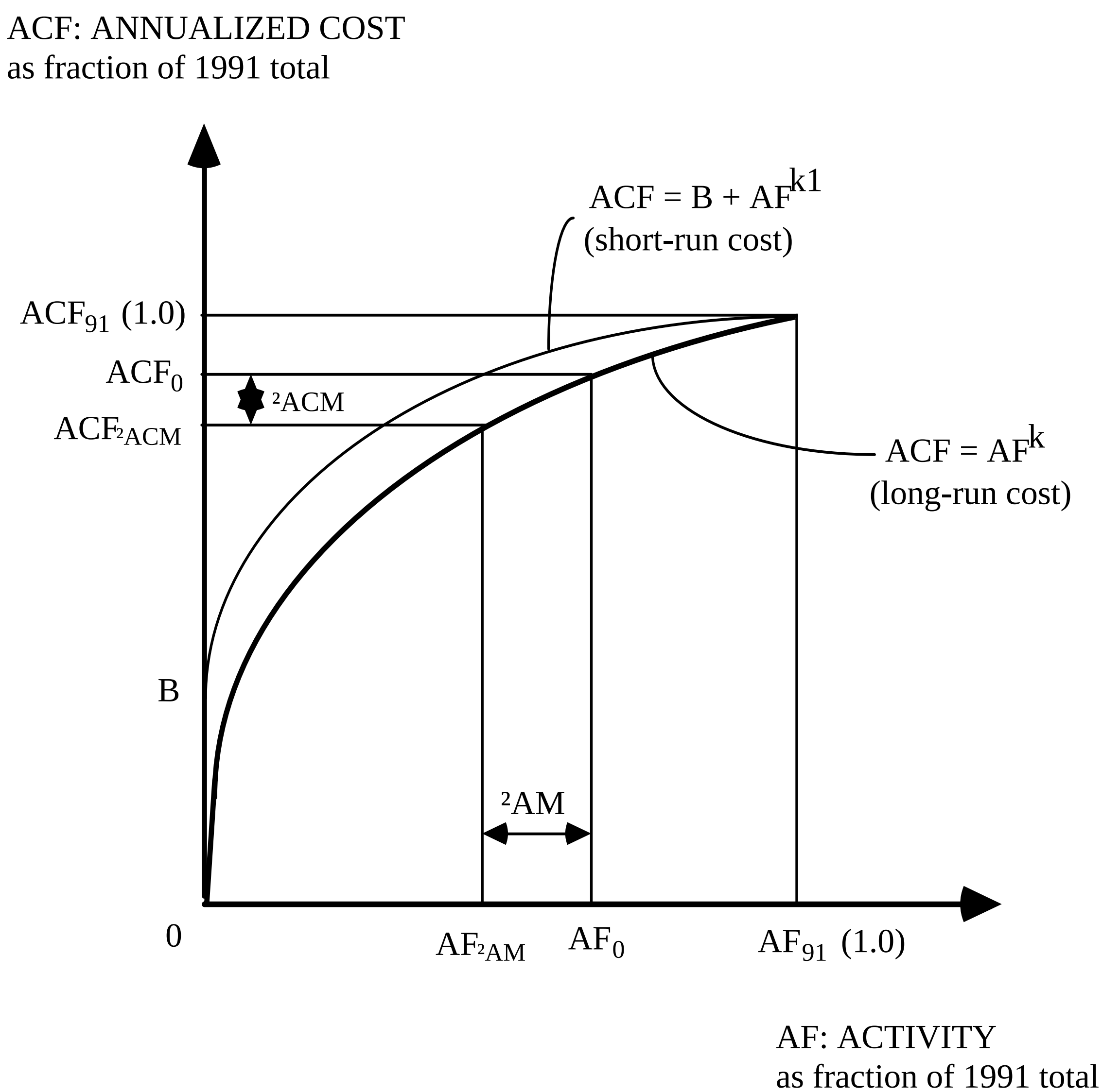

FIGURE 7-2. ESTIMATION OF MOTOR-VEHICLE RELATED ACTIVITY, AS A FUNCTION OF MOTOR-VEHICLE USE