

6. Cost Summary and Analysis

This chapter summarizes and analyzes the cost estimates from previous chapters.

Chapter Index

6.1 Discussion.....	1
6.2 Categorizing Costs.....	4
6.3 Total Transportation Costs.....	11
6.4 Cost Ranges.....	12
6.5 Survey Test of Cost Estimates.....	13
6.6 Conclusions.....	15

6.1 Discussion

Previous chapters in this report provided monetized estimates of 23 costs for 11 modes under three travel conditions. These values are included in the Transportation Cost Analysis Spreadsheet available at the VTPI website (www.vtpi.org/tca/tca.xls). This chapter summarizes and analyzes these costs. When working with these data it is important to remember:

- They include non-market costs such as users' travel time, crash risk, and environmental impacts. This is why they are higher than cost estimates that consider only monetary costs.
- Estimates reflect average vehicles and conditions in the USA. Costs may vary significantly depending on circumstances (vehicle type, location and time).
- Some costs are estimated per *vehicle* mile, while others are estimated per *passenger* mile, assuming average vehicle occupancy.

Table 6.1- 1 describes the twenty three cost categories in this study. Table 6.1-2 describes the eleven travel modes.

Table 6.1-1 Transport Cost Categories

Cost	Description
Vehicle Ownership	Fixed costs of owning a vehicle.
Vehicle Operation	Variable vehicle costs, including fuel, oil, tires, tolls and short-term parking fees.
Operating Subsidies	Financial subsidies for public transit services.
Travel Time	The value of time used for travel.
Internal Crash	Crash costs borne directly by travelers.
External Crash	Crash costs a traveler imposes on others.
Internal Activity Benefits	Health benefits of active transportation to travelers (a cost where foregone).
External Activity Benefits	Health benefits of active transportation to society (a cost where foregone).
Internal Parking	Off-street residential parking and long-term leased parking paid by users.
External Parking	Off-street parking costs not borne directly by users.
Congestion	Congestion costs imposed on other road users.
Road Facilities	Roadway facility construction and operating expenses not paid by user fees.
Land Value	The value of land used in public road rights-of-way.
Traffic Services	Costs of providing traffic services such as traffic policing, traffic lights, emergency services for traffic crashes, etc.
Transport Diversity	The value to society of having a diverse transport system, particularly travel options for non-drivers and lower-income people.
Air Pollution	Costs of vehicle air pollution emissions.
Greenhouse Gas Pollution	Lifecycle costs of greenhouse gases that contribute to climate change.
Noise	Costs of vehicle noise pollution emissions.
Resource Externalities	External costs of resource consumption, particularly petroleum.
Barrier Effect	Delays that roads and traffic cause to nonmotorized travel.
Land Use Impacts	Economic, social and environmental impacts that result from low-density, automobile-oriented development patterns.
Water Pollution	Water pollution and hydrologic impacts caused by transport facilities and vehicles.
Waste	External costs associated with disposal of vehicle wastes.

This table defines the 23 transport cost categories evaluated in this study. See individual chapters for more detailed descriptions.

Table 6.1-2 Transport Modes

Mode	Description
Average Automobile	A medium sized car that averages 21 mpg overall (16 mpg city driving, 24 mph highway driving), driven 12,500 miles per year. Occupancy averages 1.5 overall and 1.1 for Urban-Peak travel.
Compact (Fuel Efficient) Car	A small four passenger car that averages 40 mpg overall (34 mpg city driving, 46 mpg highway driving).
Electric Car	A medium size electric car based on current technology that averages 0.5 kWh per vehicle-mile.
Van or Light Truck	A 14 passenger van or light truck that averages 15 mpg overall (14 mpg city and 20 mph highway driving). Occupancy is same as an automobile.
Rideshare Passenger	The incremental cost of an additional carpool, vanpool or transit rider, assuming the vehicle would be traveling anyway.
Diesel Bus	A 40 foot bus with 25 Urban-Peak, 8 Urban Off-Peak, 5 Rural and 10 Overall Average passengers, averaging 4.0 mpg.
Electric Bus/Trolley	A 65 maximum passenger bus or trolley 30 Urban-Peak, 10 Urban-Offpeak, and 14 Overall Average passengers, averaging 6.5 mpg energy consumption equivalent.
Motorcycle	A medium size motorcycle that averages 45 mpg urban and 55 mph rural fuel efficiency.
Bicycle	A moderate priced bicycle ridden an average of 10 mph.
Walk	A person walking an average of 3 mph.
Telework	Two 11 mile commute trips avoided when employees work from home.

This table describes the eleven transport modes evaluated in this study. See Chapter 5.0 for more information.

6.2 Categorizing Costs

The transport costs can be categorized in various ways, as indicated in Table 6.2-1.

Table 6.2-1 Costs Categorized¹

Cost	Internal/ External	Fixed/ Variable	Market/ Non-market	Direct/ Indirect	Tax Based
Vehicle Ownership	Internal	Fixed	Market	Direct	
Vehicle Operation	Internal	Variable	Market	Direct	
Operating Subsidies	External	Fixed	Market	Direct	Tax Based
Travel Time	Internal	Variable	Non-Market	Direct	
Internal Crash	Internal	Variable	Non-Market	Direct	
External Crash	External	Variable	Non-Market	Direct	
Internal Activity Benefits	Internal	Variable	Mixed	Mixed	
External Activity Benefits	External	Variable	Mixed	Mixed	Part Tax Based
Internal Parking	Internal	Fixed	Market	Direct	
External Parking	External	Variable	Market	Direct	20% Tax Based
Congestion	External	Variable	Mixed	Direct	
Road Facilities	External	Variable	Market	Direct	Tax Based
Land Value	External	Variable	Mixed	Mixed	Tax Based
Traffic Services	External	Variable	Market	Direct	Tax Based
Transport Diversity	External	Variable	Non-Market	Indirect	
Air Pollution	External	Variable	Non-Market	Mixed	
Greenhouse Gas	External	Variable	Mixed	Mixed	
Noise	External	Variable	Non-Market	Direct	
Resource Externalities	External	Variable	Mixed	Indirect	
Barrier Effect	External	Variable	Non-Market	Direct	
Land Use Impacts	External	Variable	Mixed	Indirect	
Water Pollution	External	Variable	Non-Market	Indirect	
Waste	External	Variable	Non-Market	Indirect	

This table indicates how the twenty transport costs can be categorized. See Chapter 1 for more information on these categories.

Table 6.2-2 shows the costs grouped into three major categories, based on how they affect travel decisions. Internal-Variable costs directly affect individual trip-making decisions. Internal-Fixed costs affect vehicle ownership, but not individual trips. External costs do not directly affect consumers' travel decisions. As discussed in Chapter 3, economic efficiency and horizontal equity require that prices (perceived-internal-variable-costs) reflect total marginal cost as much as possible. External costs, and some internal costs (those that are often not accurately perceived by motorists such as crash risk) fail to give motorists accurate market signals, and therefore tend to lead to excessive travel.

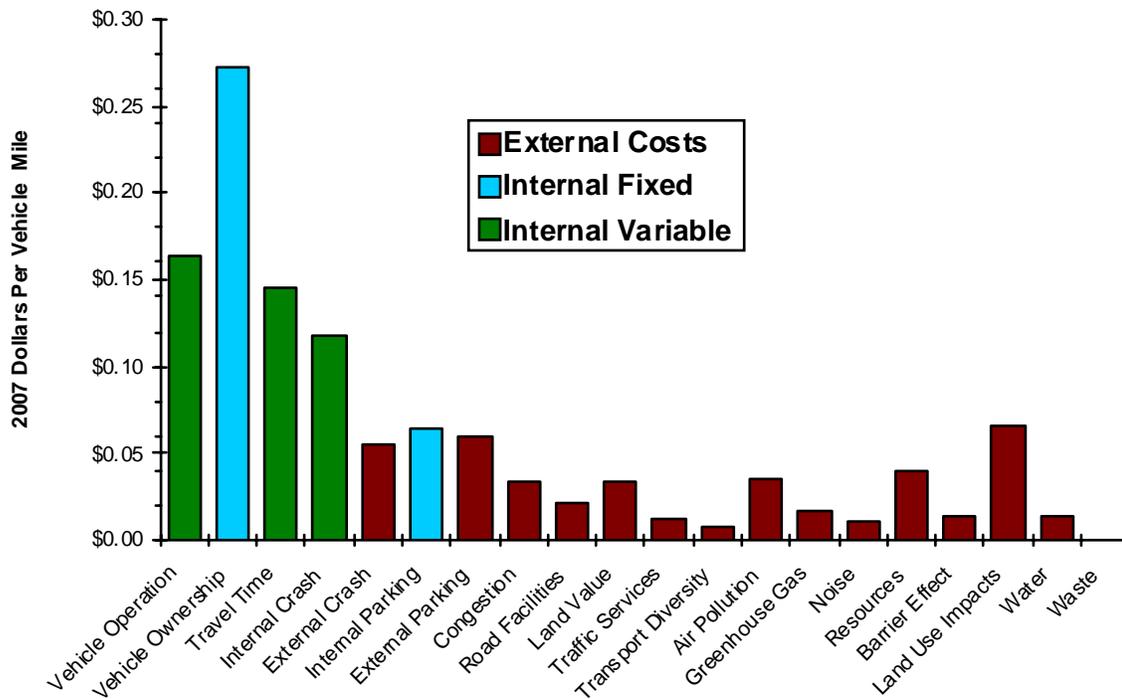
¹ Of course, some costs do not fall perfectly into these categories. This table shows dominant tendencies.

Table 6.2-2 Costs Grouped by Their Dominant Travel Impacts

Internal Variable	Internal Fixed	External
Directly affects individual trip making decisions.	Affects vehicle ownership, but once paid does not affect individual trip decisions.	Does not directly affect consumers' travel decisions.
Vehicle Operation Travel Time Internal Crash Internal Health	Vehicle Ownership Internal Parking	Operating Subsidies External Crash External Health External Parking Congestion Road Facilities Land Value Traffic Services Transport Diversity Air Pollution Greenhouse Gas Noise Resource Externalities Barrier Effect Land Use Impacts Water Pollution Waste

This table categories costs based on how they affect travel. Note that these are the dominant categories for each cost but there is some variation, such as some internal parking costs are variable. See chapter 3 for more information.

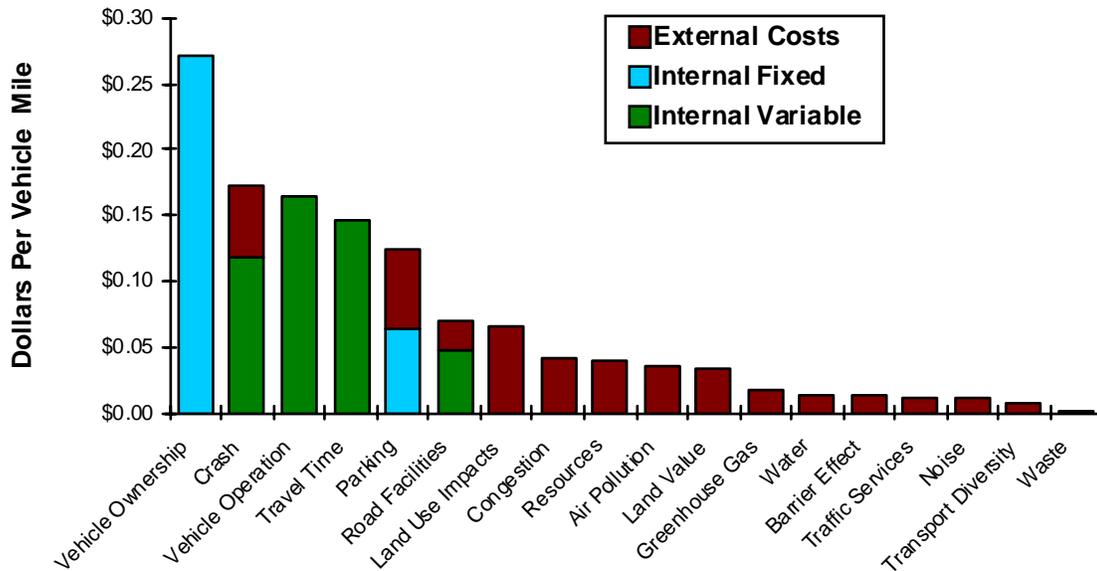
Figure 6.2-1 Costs Per Vehicle Mile for Average Car



This figure shows Average Car costs per vehicle mile.

Figure 6.2-1 illustrates the estimated magnitude of costs per vehicle mile for an Average Car. Figure 6.2-2 illustrates the costs for an Average Car ranked by magnitude, with internal and external components combined. This shows that the largest categories of costs tend to be internal, including vehicle ownership, travel time, vehicle operation and crash risk borne directly by individual motorists. External costs tend to be smaller, and so are easy to overlook, but numerous, so their aggregate value tends to be significant.

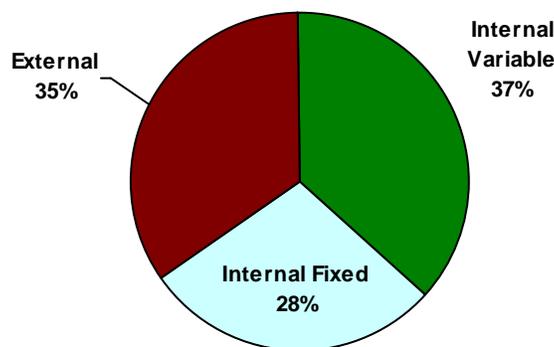
Figure 6.2-2 Costs Ranked by Magnitude



This figure shows Average Car costs per vehicle mile, ranked by magnitude.

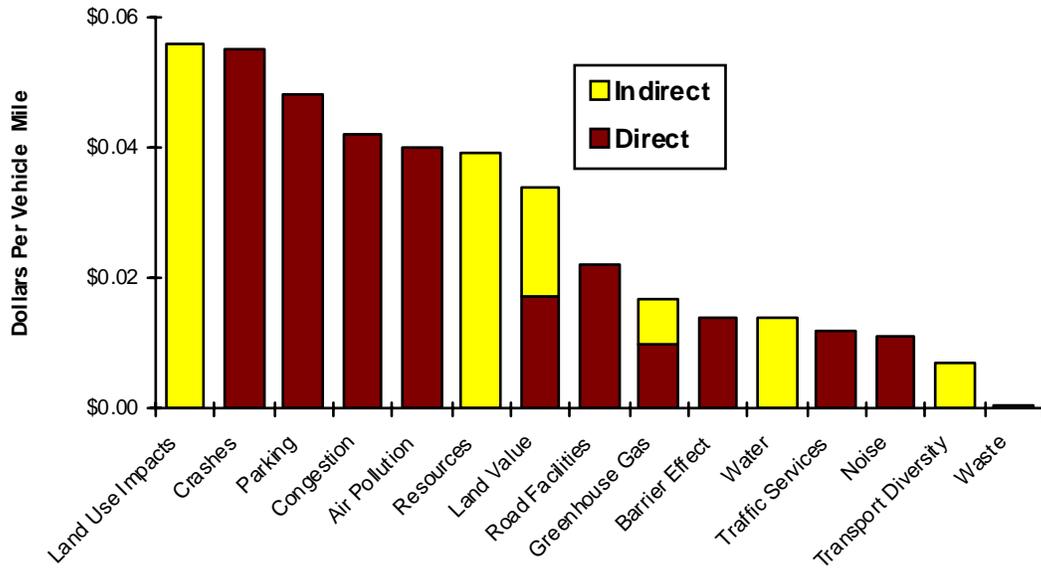
Figure 6.2-3 shows the distribution of costs aggregated. About a third of total costs are External and about a quarter are Internal-Fixed, leaving less than half Internal-Variable, indicating significant underpricing (prices are significantly below total costs).

Figure 6.2-3 Average Car Cost Distribution



This figure illustrates the aggregate distribution of costs for an average car. About 60% of total vehicle costs are either External or Internal-Fixed.

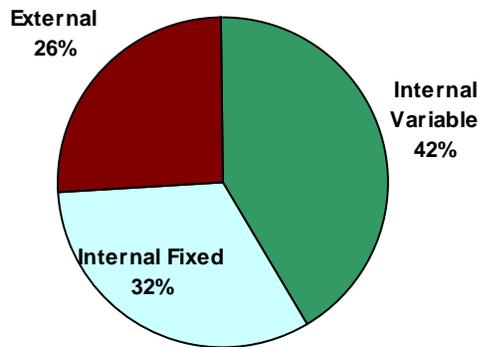
Figure 6.2-4 External Costs Ranked by Magnitude



This figure shows Average Car external costs per vehicle mile, ranked by magnitude.

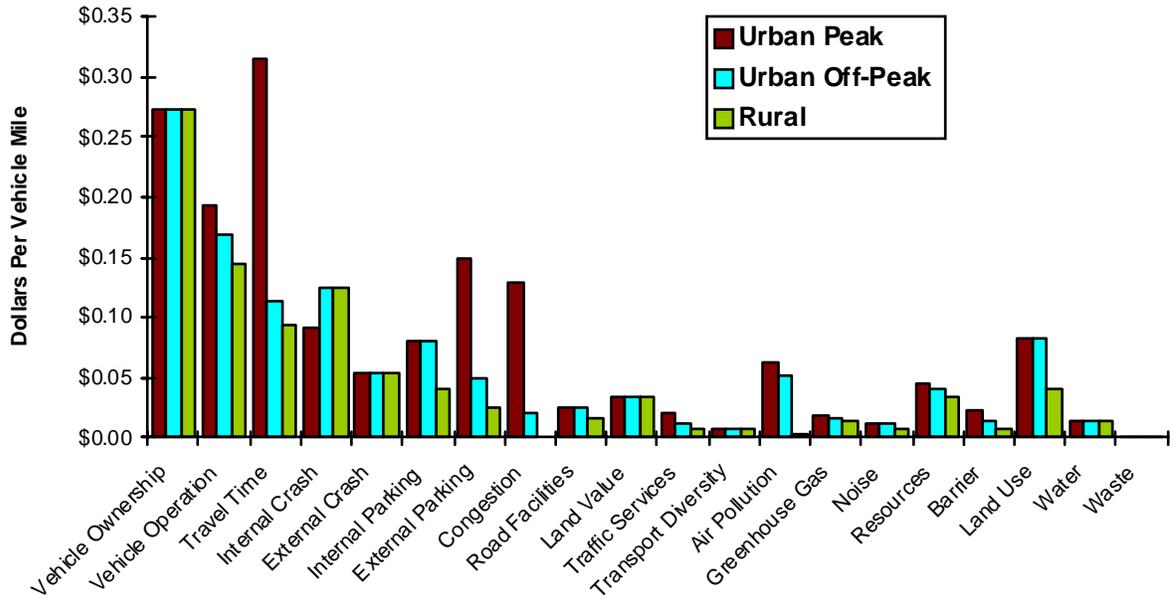
Figure 6.2-4 examines just the external costs. It identifies those costs that can be considered “indirect,” and so may be unsuited for inclusion in some types of evaluation, as discussed in Chapter 3. Figure 6.2-5 shows the distribution of cost if these indirect costs are excluded (compare it with Figure 6.2-3). Even with this narrower definition of external costs, less than half of total automobile costs are Internal-Fixed, indicating significant underpricing.

Figure 6.2-5 Cost Distribution Excluding “Indirect” External Costs



This figure illustrates the aggregate distribution of costs for an average car, excluding indirect costs such as land use impacts, transportation diversity benefits and water pollution and waste disposal externalities. Still, well over half of vehicle costs are either External or Internal-Fixed.

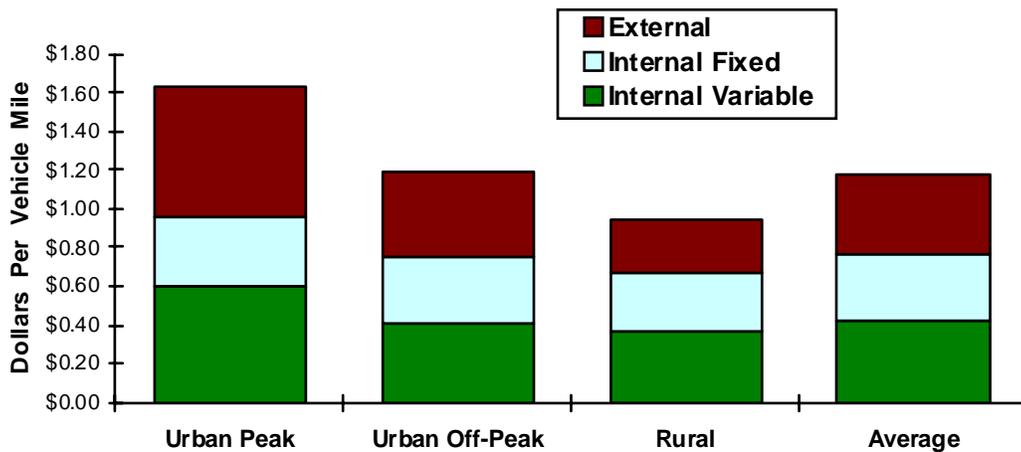
Figure 6.2-6 Costs for Average Automobile Under Three Travel Conditions



Some costs are higher under urban and peak-period travel conditions, for example travel time costs are higher since speeds are slower and time is valued at a much higher rate. In contrast, internal crash risk per vehicle mile is lower at peak periods since vehicle occupancy is lower.

Figure 6.2-6 shows how these costs vary under the three travel conditions. Some costs, such as vehicle operation, travel time, parking, congestion and air pollution, vary significantly depending on when and where driving occurs. Other costs, such as greenhouse gas emissions, are less affected. Figure 6.2-7 illustrates how aggregate costs vary by travel conditions.

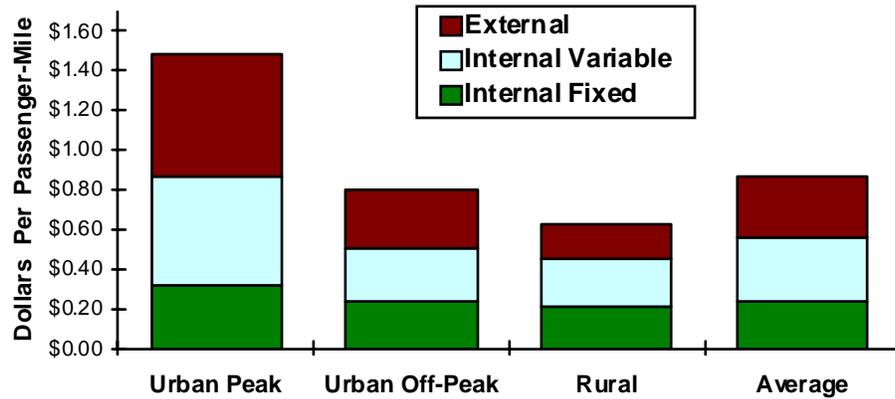
Figure 6.2-7 Average Car Cost Distribution By Driving Conditions



This figure illustrates how aggregate costs vary by travel conditions. Urban-Peak travel has the largest total costs largely due to higher external costs.

Figure 6.2-8 shows the distribution of costs per *passenger-mile*, which is calculated by dividing costs per vehicle-mile by average vehicle occupancy. Urban-peak travel has relatively high costs because peak-period vehicle occupancy tends to be lower than average (1.1 passengers per vehicle compared with 1.42 for other travel conditions).

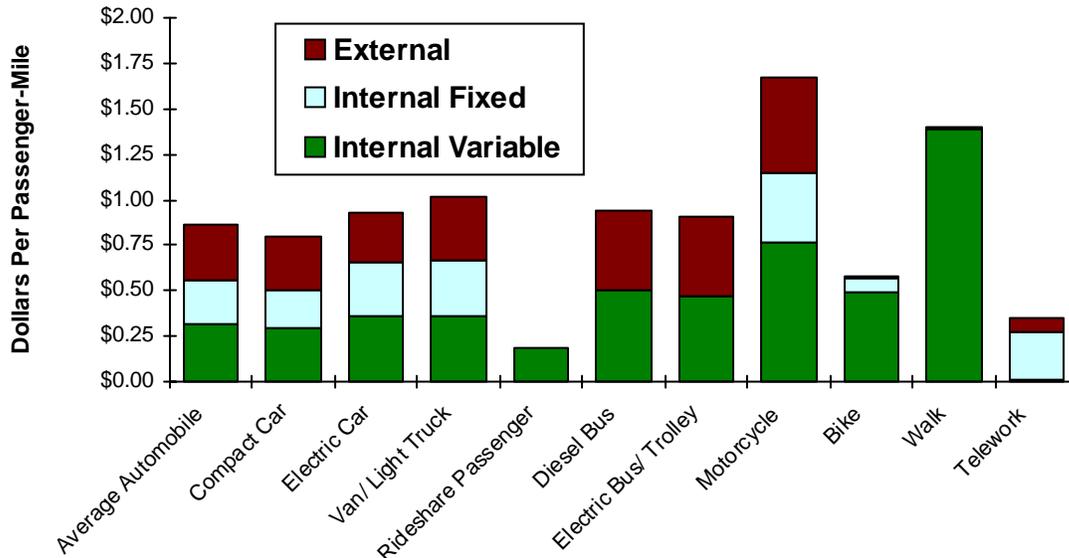
Figure 6.2-8 Average Car Costs Per Passenger-Mile



This figure illustrates how aggregate costs per passenger-mile vary by travel conditions, taking into account differences in vehicle occupancy. Urban-peak vehicle occupancy is low; therefore urban peak passenger mile costs are high compared to the other categories.

Figure 6.2-9 compares costs per passenger-mile for each of the eleven modes. Both the magnitude and the distribution of costs vary significantly between modes.

Figure 6.2-9 Cost Distribution by Mode



This graph shows the cost distribution of each mode. These costs are measured per passenger-mile, not per vehicle-mile, as in previous graphs. Note that transit costs are based on average U.S. ridership levels and would be lower in areas with higher ridership rates.

Costs only vary slightly between different types of automobiles. Compared with an Average Car, a Compact or alternative-fuel car reduces some costs, while vans and pickup trucks increase some. Motorcycles have relatively high costs due to their high crash and pollution costs and low average annual mileage (so fixed costs are divided among fewer miles). Transit modes have relatively high average costs reflecting low densities and ridership in the US, while ridesharing (a passenger using an otherwise empty seat) has the lowest costs, consisting almost entirely of travel time. Walking and cycling costs also consist primarily of travel time. Telework tends to involve some fixed costs for additional computer equipment and communications services.

Special consideration is needed when comparing different modes, since their costs can vary depending on travel conditions, personal preferences, and analysis assumptions. For example, in some situations, walking, cycling and public transit are difficult and uncomfortable and so have high unit time costs, as discussed in the Travel Time costs chapter, but in other situations people prefer using these modes even if they take longer. Although they may take longer, the time is charged at a lower rate per minute. As a result, giving people the option of walking and cycling in pleasant conditions can provide significant user benefits, allowing people to select the mode they prefer. If cycling or walking improvements or other positive incentives induce people to shift from driving to alternative modes, they must be better off overall, regardless of increased travel time, or they would not change. Public transit ridership often experiences increasing economies of scale, since many costs are fixed and many transit systems have excess capacity.² When this is true, Diesel Bus and Electric Bus/Trolley cost values overstate marginal costs, so the costs of shifts to these modes is best reflected in the Rideshare Passenger cost estimate, which is the incremental cost of an additional passenger.

Table 6.2-3 shows the estimated external cost savings resulting travel shifts to alternative modes. For example, each passenger-mile shifted from Urban-Peak to Off-peak travel reduces estimated external costs by about 33¢. Each passenger-mile shifted from an Average Car to a Rideshare Passenger provides savings estimated at 62¢ during peak periods and 36¢ off peak.

Table 6.2-3 External Savings Due To Travel Shifts (\$ Per Passenger-Mile)

	Peak Shifting	Compact Car	Electric Car	Rideshare Passenger	Diesel Bus	Electric Trolley	Bicycle	Walk	Tele-work
Urban-Peak	\$0.33	\$0.03	\$0.06	\$0.62	\$0.24	\$0.21	\$0.69	\$0.85	\$0.53
Urban Off-Peak	N/A	\$0.02	\$0.04	\$0.29	\$-0.16	\$-0.15	\$0.38	\$0.52	\$0.21
Rural	N/A	\$0.01	\$0.02	\$0.18	\$-0.28	\$-0.25	\$0.27	\$0.41	\$0.13
Average	N/A	\$0.02	\$0.03	\$0.31	\$-0.13	\$-0.12	\$0.39	\$0.54	\$0.24

This table indicates the estimated external cost savings (reductions in vehicle costs, congestion, parking, roadway costs, etc.) due to a shift from Average Car travel to another mode. Negative values for off-peak and average transit reflect low average ridership on buses in the US.

² Todd Litman (2008), *Evaluating Public Transit Benefits and Costs*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tranben.pdf

6.3 Total Transportation Costs

Table 6.3-1 shows estimated U.S. automobile travel costs based on this analysis.

Table 6.3-1 Motor Vehicle Costs, by Mile and Total (2007)

	Mileage	Internal Costs		External Costs		Total Costs	
	(billions)	Per Mile	Total (billions)	Per Mile	Total ³ (billions)	Per Mile	Total (billions)
Urban-Peak	600	\$0.95	\$572	\$0.55	\$331	\$1.51	\$904
Urban Off-Peak	1200	\$0.76	\$910	\$0.42	\$503	\$1.18	\$1,412
Rural	1200	\$0.67	\$809	\$0.27	\$322	\$0.94	\$1,130
<i>Total</i>	<i>3,000</i>		<i>\$2,291</i>		<i>\$1,156</i>		<i>\$3,446</i>

This table summarizes total motor vehicle costs based on the estimates from this report.

This \$3.4 trillion total equals about 25% the U.S. Gross Domestic Product (GDP),⁴ which may seem unreasonably high, but these are mostly non-market costs, such as personal time, crash risk and environmental degradation, and so are excluded from standard GDP calculations. The market economy can be imagined as the tip of a pyramid, based on the non-market human economy (unpaid travel time and work that contribute to society), based on the natural economy (natural resources such as clean air and water), illustrated in Figure 6.4-1.⁵ In other words, we are much richer than indicated by just our financial assets due to these non-market goods. Non-market costs, such as crash risk, personal time, and environmental degradation, represent a loss of valuable resources to ourselves, other members of society and future generations. These estimates indicate what it would cost if the non-market goods consumed by transport required compensation.

Figure 6.3-1 Market, Human Non-Market, and Natural Non-Market Goods



Markets represent only a small portion of all human benefits. A larger portion of benefits are provided by human non-market and natural non-market goods (sometimes called “natural capital”). Many of the costs of transportation represent losses of these goods.

³ Congestion costs are excluded from these totals, since this would double-count users’ travel time and vehicle operating costs. Congestion is external at the individual level, but internal at the sector level

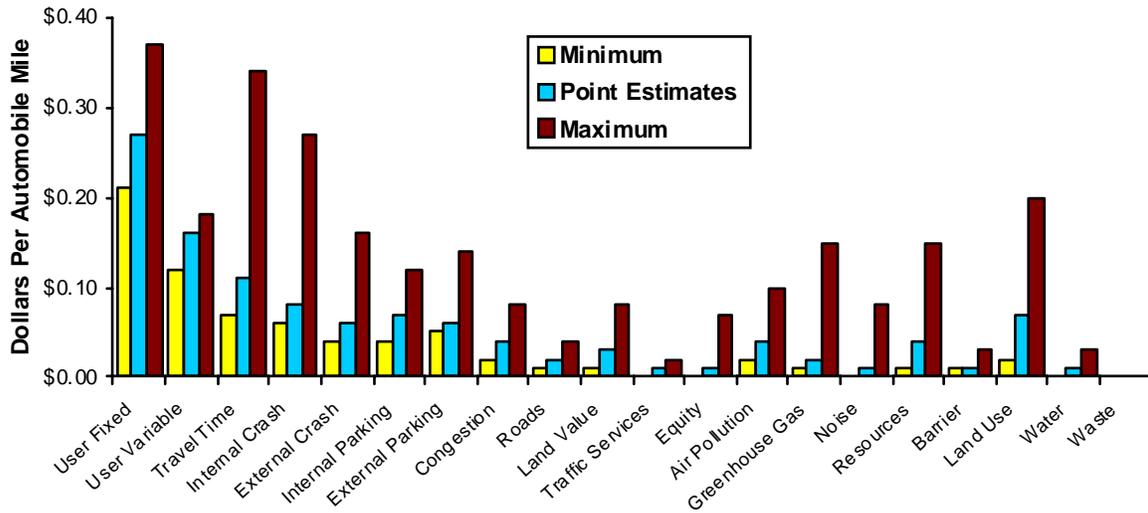
⁴ US GDP was \$13,807 billion in 2007. BEA (2008), National Income and Product Accounts Table Table 1.1.5. Gross Domestic Product, (www.bea.gov).

⁵ Robert Costanza, et al. (1997), “The Value of the World’s Ecosystem Services and Natural Capital,” *Nature*, Vol. 387 (www.nature.com), 15 May, pp. 253-260.

6.4 Cost Ranges

Cost estimates in this report incorporate various degrees of uncertainty, as discussed in Chapter 1. The point estimates used for analysis in this chapter actually represent a range of possible costs that reflect uncertainty in the data. Figure 6.5-1 illustrates the Minimum and Maximum estimates provided for each cost.

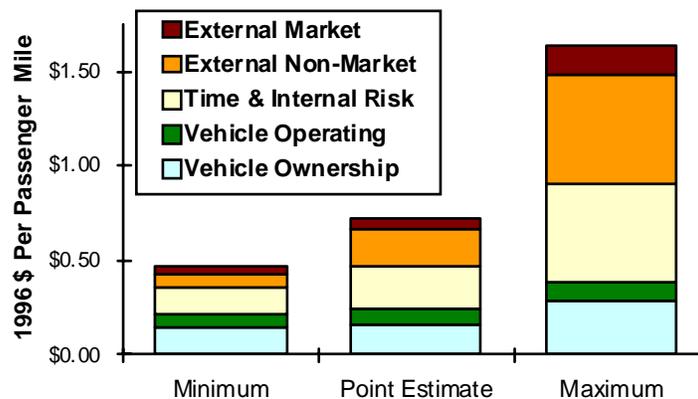
Figure 6.4-1 Ranges of Average Automobile Costs



This graph shows the most likely range for each cost.

Figure 6.4-2 shows Minimum, Point and Maximum estimates. Even the Minimum estimate shows external costs to be approximately equal to the Maximum estimate of variable vehicle costs (fuel, oil, tires, maintenance, and short term parking). Thus, even if the lowest reasonable values are used for each cost, externalities are still significant relative to costs considered in individual's trip by trip transportation decisions.

Figure 6.4-2 Ranges of Average Automobile Costs by Major Category



This graph compares cost range by major categories.⁶

⁶ This chart is in 1996 dollars, using data from the previous version of this document.

6.5 Survey Test of Cost Estimates

Since only limited data are available on some costs included in this study, a survey was performed to determine whether this study’s results are consistent with popular values and perceptions.⁷ One hundred surveys were distributed to households randomly selected across North America. Thirty-eight completed survey forms were received.

The survey asked respondents to identify how serious they consider various transportation problems. The responses were numbered from 1 (Very Serious) to 4 (Not At All Serious). Table 6.5-1 shows the survey results. These indicate that the public considers social and environmental transportation costs significant. Even the lowest ranking cost, *Ugliness of roads*, has a value indicating that respondents, on average, consider it between “Not Very Serious” and “Somewhat Serious.” Survey results are well correlated to the ranking of average automobile costs in this study, with the exception of urban sprawl, which the survey results ranked much lower than this study.

Table 6.5-1 Public Survey and This Study's Cost Estimate Ranking Compared
“Below is a list of transportation problems. Please indicate how serious you consider each.”

Survey Rank	Rank In This Study	Transportation Problems	Survey Average	Variance
1	1	Traffic accidents	1.53	0.72
2	3	Air Pollution	1.59	0.45
3	5	Excessive energy consumption.	1.74	0.37
4	4	Traffic congestion	1.89	0.84
5	7	Barrier Effect	2.19	0.50
6	8	Traffic noise	2.20	0.87
7	9	Mobility problems for non-drivers	2.24	0.50
8	6	Harm to wildlife caused by roads and traffic.	2.27	0.64
9	2	Urban sprawl	2.37	0.86
10	10	Ugliness of roads	2.79	0.90

This table shows that survey respondents gave similar rankings to costs as this study. (Note: the lower the average value the more serious respondents consider the problem.)

A second question asked respondents to identify how important they consider various transportation goals (Table 6.5-1). “Very Important” counted as a 1, while “Not At All Important” counted as a 4. Although these questions are more difficult to compare directly, the results are consistent with this study’s cost estimates. The top ranking of *Develop a more diverse transportation system*, and *Provide better transport to poor, handicapped, and elderly*, indicate a value to transportation diversity, and that the values used in this report are, if anything, too low. Similarly, the high ranking of *Reduce environmental impacts* and *Reduce urban impacts* indicate that the public perceives environmental degradation and negative social impacts to be significant external costs of our current transport system.

⁷ This refers to a previous version of this document, which did not separate greenhouse gas emissions from other types of air pollution.

Table 6.5-2 Survey Ranking of Transportation Goals
“Please indicate how important you consider the following transportation goals.”

Rank	Question	Average	Variance
1	Develop more diverse transportation system.	1.26	0.20
2	Provide better transport to poor, handicapped, and elderly.	1.58	0.44
3	Reduce environmental impacts.	1.74	0.81
4	Reduce urban impacts.	1.77	0.39
5	Reduce/avoid urban sprawl	2.21	0.92
6	Accommodate increased driving	2.34	0.81

While its small size and methodological limitations prevent this survey from providing conclusive results, it supports this study’s estimates of transportation costs and demonstrates that surveys can be useful for this research. Survey results indicate that the magnitudes of this study’s cost estimates are appropriate, and that costs which have previously been ignored in transport planning, such as Equity, Option Value, Barrier Effect, and Land Use Impacts, are considered significant by the public.

6.6 Conclusions

If you ask people what it costs to drive they typically mention vehicle operating expenses, which average approximately 16¢ per mile for a typical automobile. Some may include vehicle ownership costs, which average about 27¢ per mile. A few may also mention travel time and crash risk. These, however, are only a portion of total costs. The full cost of driving includes these direct, internal costs, plus various indirect and external costs. Total estimated costs range from about \$0.94 per vehicle mile for rural driving to \$1.64 for urban-peak driving. Of course there is considerable variation in the costs of any specific trip, but these estimates, and variations for different travel modes and specific conditions, provide a reasonable basis for analyzing true transport costs.

The largest categories of transport costs tend to be internal, including vehicle ownership and operation, travel time, and crash risk borne by motorists. External costs tend to be smaller, and so are easy to overlook, but numerous, so their aggregate value tends to be significant. About half of transport costs are either external or internal-fixed, and therefore do not directly affect individual travel decisions. This represents underpricing, which results in economically excessive automobile travel (more vehicle travel than would occur in a more efficient market). Other forms of transport have other cost profiles, some having much smaller external costs under certain circumstances.

Table 6.6-1 illustrates the estimated net external cost savings that result when a typical urban commuter shifts from driving an average automobile an alternative mode, including savings in parking, congestion, roadway facility costs, crash risk imposed on other road users, and environmental impacts.⁸ This indicates the upper range of what a community should be willing to invest in mobility management strategies that result in such mode shifts. Of course, actual costs will vary depending on specific conditions.

Table 6.6-1 Daily External Savings Due To Commute Mode Shifts

Peak Shifting	Compact Car	Electric Car	Rideshare Passenger	Diesel Bus	Electric Trolley	Bicycle*	Walk*	Telework
6.55	0.60	1.18	12.35	4.79	4.15	12.99	13.37	10.63

*This table indicates the estimated external cost savings (reductions in congestion, parking, roadway costs, etc.) due to a shift from Average Car to another mode for a typical peak period 20-mile round trip urban commute. * Health benefit values for cycling have been capped at 12 miles, and walking at 5 miles; these values represent the land use changes allowing 20-mile automobile commutes to be replaced with 12 and 5 mile active transport commutes respectively.*

Some external costs are indirect, and estimates of their magnitude incorporate various degrees of uncertainty, but these factors do not fundamentally change the analysis conclusions. The existence of each cost can be demonstrated, double counting is avoided, and the best available data are used. Even using lower-bound estimates, external costs are significant compared in magnitude to costs normally considered in transport planning.

⁸ Todd Litman (2007), *Guide to Calculating Mobility Management Benefits*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tdmben.pdf.