6. Cost Summary and Analysis

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

Previous chapters in this report provided monetized estimates of 20 costs for 11 modes under three travel conditions, totaling 660 individual cost values. 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. 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 describes the twenty costs categories in this study. Table 6.2 describes the eleven travel modes.

Table 6-1 **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 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.
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 twenty transport cost categories evaluated in this study. See individual chapters for more detailed descriptions.

Table 6-2 **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, which consumes an average of 0.5 kWh per mile of travel.
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 average passengers during peak periods, 8 average passengers during Urban Off-Peak, and 5 average passengers during rural travel, an overall average occupancy of 10 passengers, averaging 4.0 mpg.
Electric Bus/Trolley	A 65 maximum passenger bus or trolley with a peak period occupancy of 30 passengers, 10 average passengers at other times, an overall average occupancy of 14 passengers, and averages 6.5 mpg energy consumption equivalent.
Motorcycle	A medium size motorcycle that averages 45 mpg under urban driving conditions, and 55 mph under rural driving conditions.
Bicycle	A moderate priced bicycle ridden an average of 10 mph.
Walk	A person walking an average of 3 mph.
Telework	This represents 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.

Categorizing Costs

The transport costs can be categorized in various ways, as indicated in Table 6-3.

Table 6-3 **Costs Categorized**[1]

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 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	
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 6-4 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-fixed costs (those that are intended to represent impacts that increase with mileage such as crash risk) fail to give motorists accurate market signals, and therefore tend to lead to excessive travel.

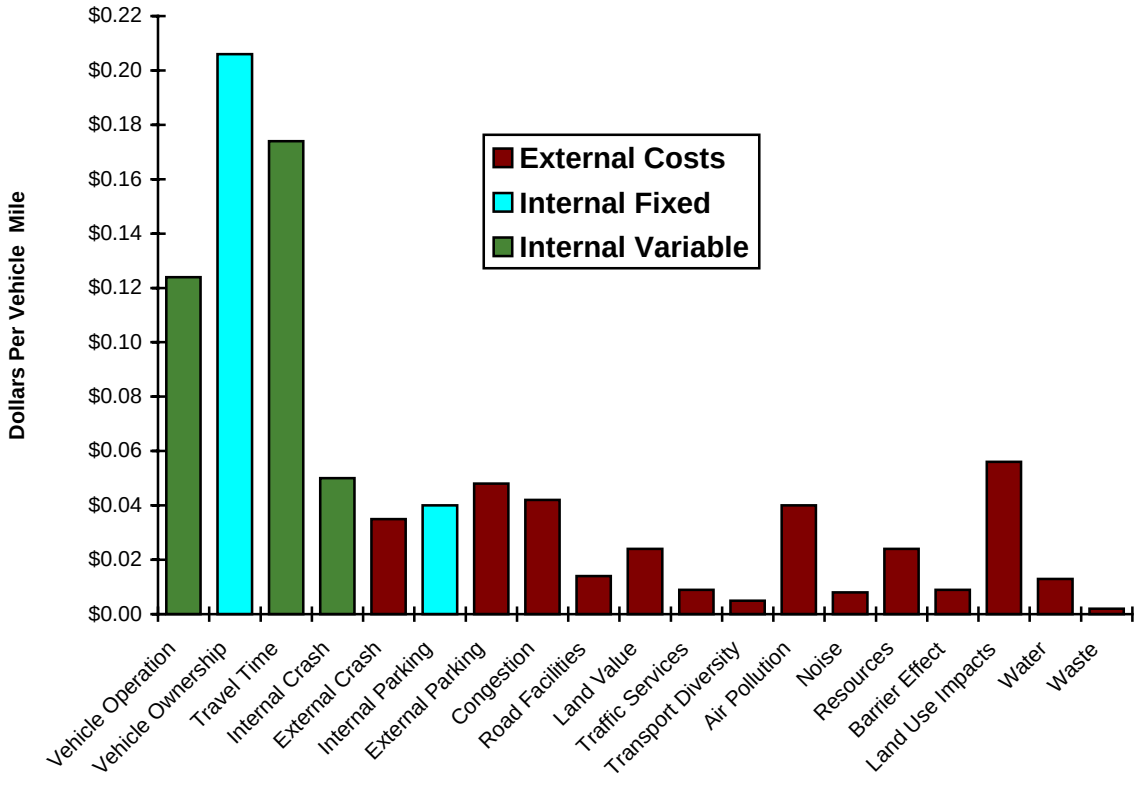
[1] Of course, some costs do not fall perfectly into these categories. This table shows dominate tendencies.

Table 6-4 **Costs Grouped by Their Travel Impacts**

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

This table categories costs based on how they affect travel. See chapter 3 for more information.

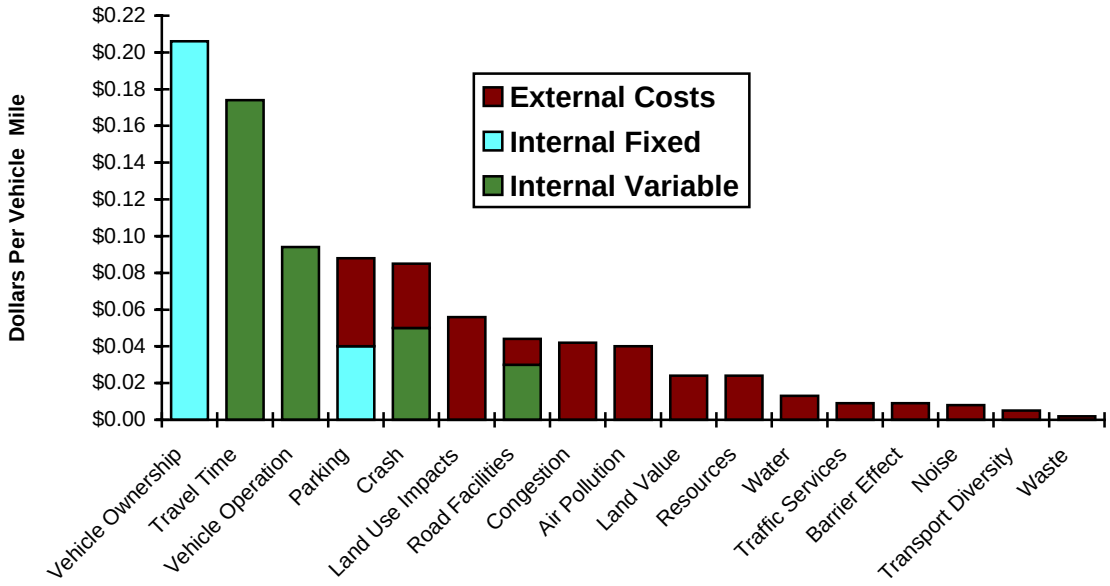
Figure 6-1 **Costs Per Vehicle Mile for Average Car**



This figure shows Average Car costs per vehicle mile.

Figure 6-1 illustrates the estimated magnitude of costs per vehicle mile for an Average Car. Figure 6.2 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.

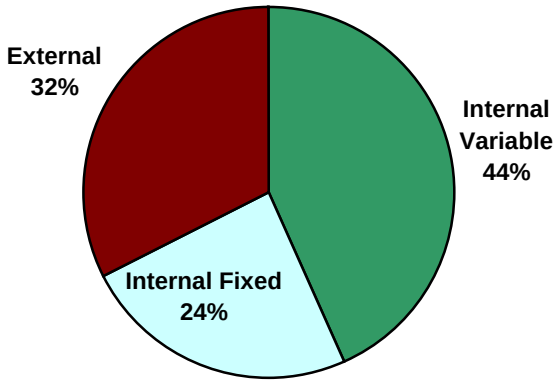
Figure 6-2 **Costs Ranked by Magnitude**



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

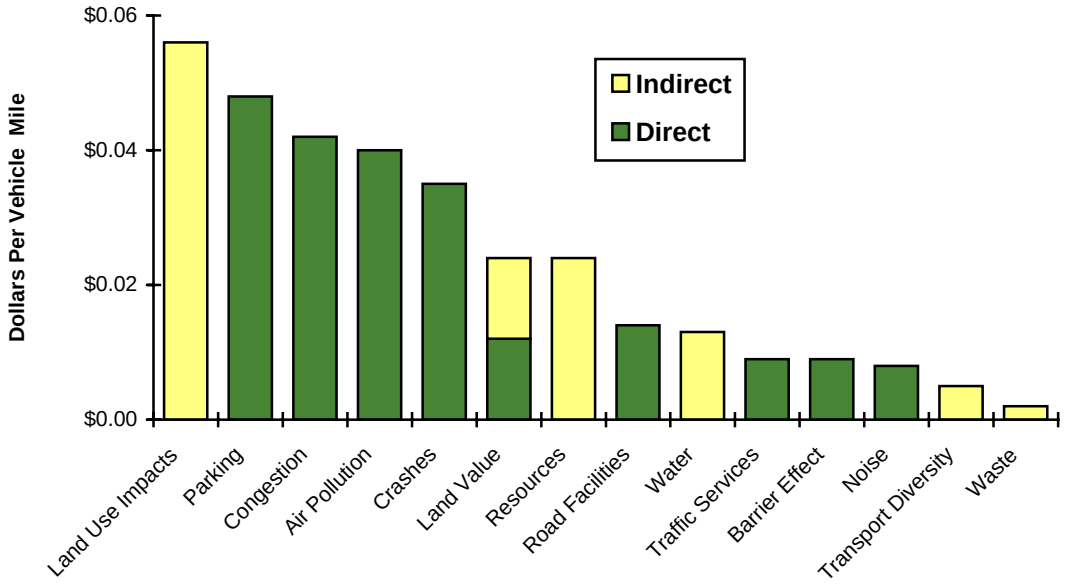
Figure 6.3 shows the distribution of costs aggregated. About a third of total costs are External and about a quarter are Internal-Fixed, leaving less than half Internal-Variable, indicating significant underpricing (prices are significantly below total costs).

Figure 6-3 **Average Car Cost Distribution**



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

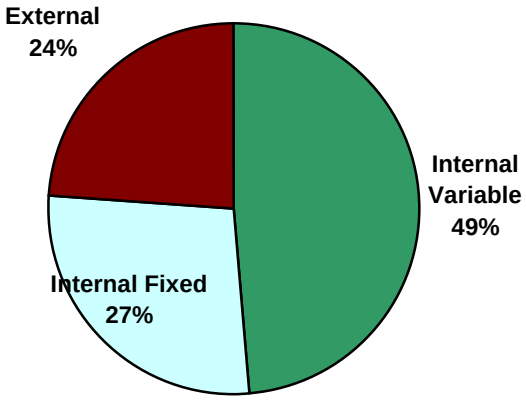
Figure 6-4 **External Costs Ranked by Magnitude**



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

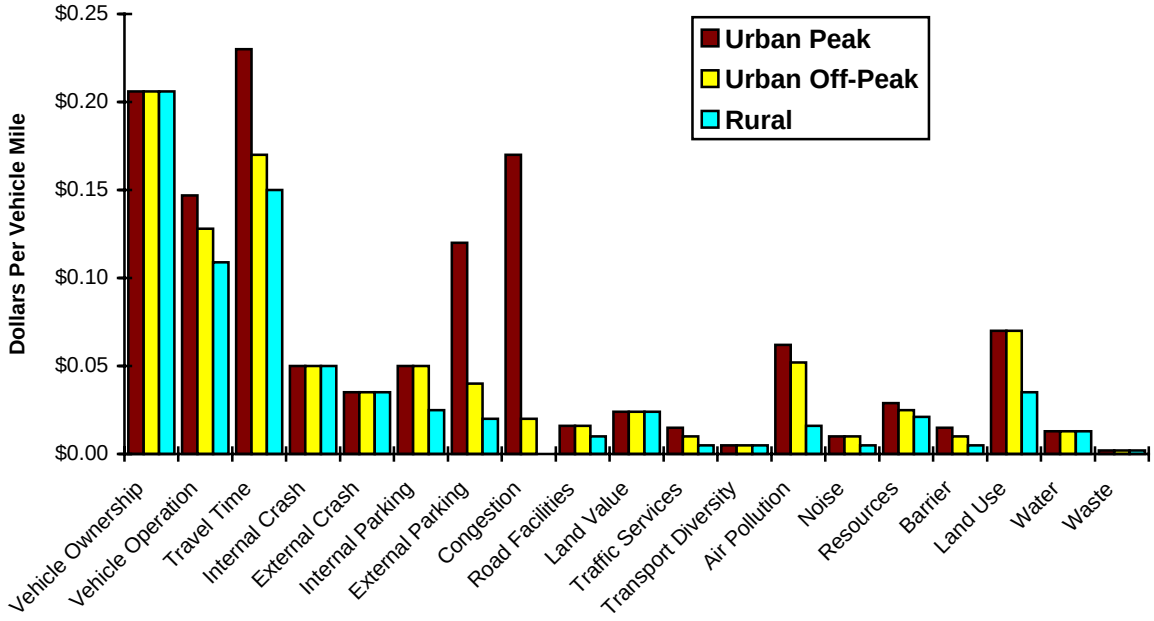
Figure 6-4 examines just the external costs. It identifies those costs that can be considered "indirect," and so may be unsuited for inclusion in some types of evaluation, as discussed in Chapter 3. Figure 6-5 shows the distribution of cost if these indirect costs are excluded (compare it with Figure 6-3). Even with this narrower definition of external costs, less than half of total automobile costs are Internal-Fixed, indicating significant underpricing.

Figure 6-5 **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, about half of vehicle costs are either External or Internal-Fixed.

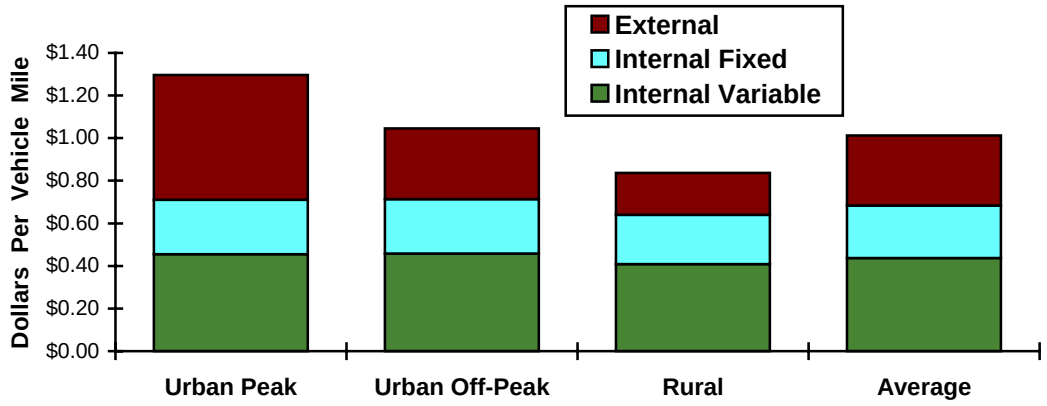
Figure 6-6 **Costs for Average Automobile Under Three Travel Conditions**



Some costs are higher under urban and peak-period travel conditions.[2]

Figure 6-6 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 are less affected. Figure 6-7 illustrates aggregate costs vary by travel conditions.

Figure 6-7 **Average Car Cost Distribution By Driving Conditions**

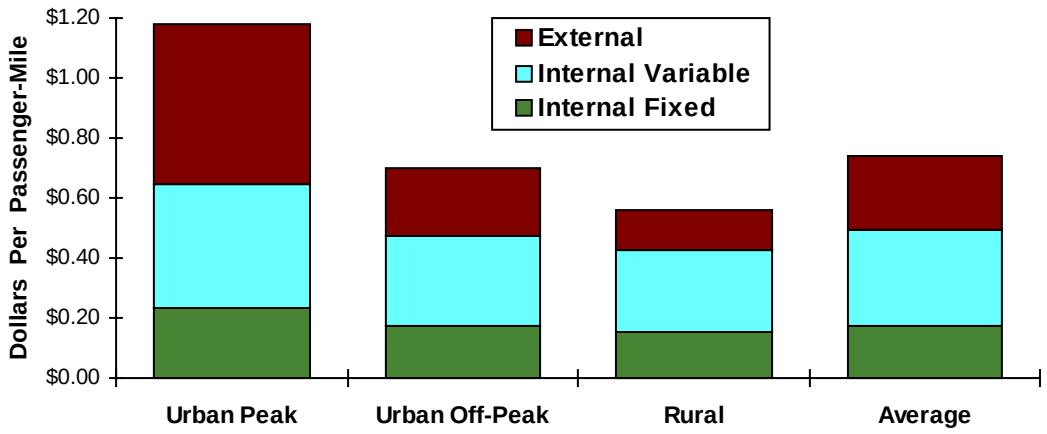


This figure illustrates how aggregate costs vary by travel conditions. Urban-Peak travel has the largest total costs largely due to higher external costs.

[2] Note that travel time and internal crash costs are higher per vehicle for off-peak than for peak travel. This is because urban peak driving tends to have lower vehicle occupancy than driving under other conditions.

Figure 6-8 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 an 1.6 for other travel conditions).

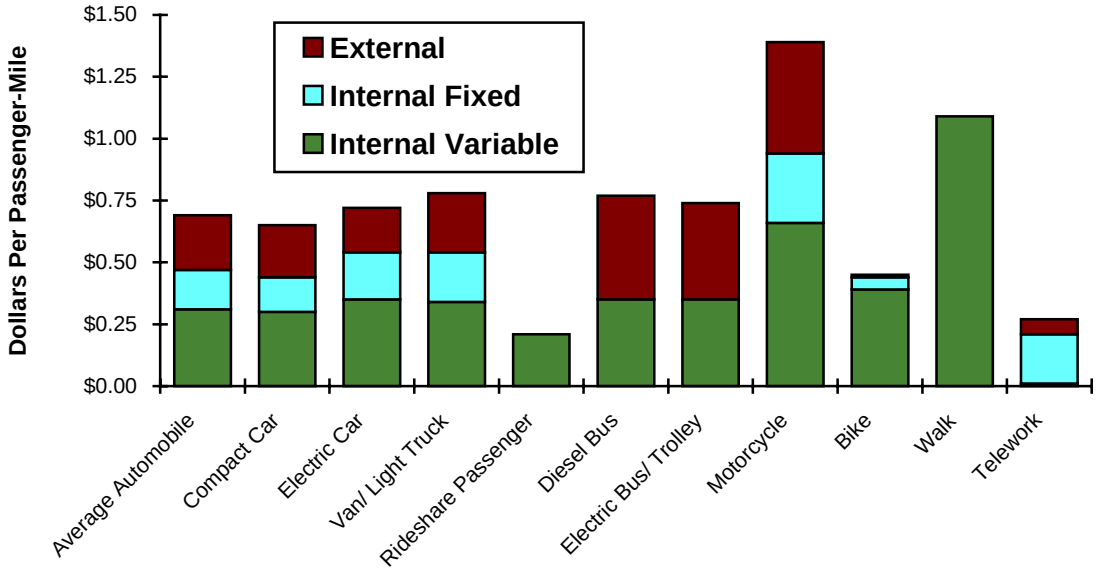
Figure 6-8 **Average Car Costs Per Passenger-Mile**



This figure illustrates how aggregate costs per passenger-mile vary by travel conditions, taking into account differences in vehicle occupancy.

Figure 6-7 compares costs per passenger-mile for each of the eleven modes. Both the magnitude and the distribution of costs varies significantly between modes.

Figure 6-7 **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.

Costs only vary slightly between different types of automobile. Compared with an Average Car, a compact or alternative-fuel car reduces some externalities, and vans and pickup trucks have somewhat greater costs. Motorcycles have relatively high costs due to their high crash and pollution costs and low average annual mileage (so fixed costs such as depreciation and insurance are divided among fewer miles). Transit modes have relatively high average costs, 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.

Several special factors should be considered when comparing the costs of different modes. For example, nonmotorized travel costs are significantly affected by the value consumers place on their travel time. In some situations, walking and cycling are difficult and uncomfortable so their travel time costs are high, but in other situations people enjoy these activities and so incur little or no additional travel time costs. For example, if cycling or walking improvements or other positive incentives induce people to voluntarily shift from driving to nonmotorized travel, they must be better off overall, regardless of changes in travel time, or they would not make the shift. Although nonmotorized trips may take longer, the time is charged at a lower rate per minute. Similarly, shifts from driving to public transit or ridesharing that result from positive incentives can be considered to provide net user benefits, regardless of changes in travel time.

Public transit ridership often experiences increasing economies of scale, since many costs are fixed and many transit systems have excess capacity.[3] When this is true, Diesel Bus and Electric Bus/Trolley cost values overstate marginal costs. The *marginal* cost of bus and trolley use on a vehicle that has excess capacity is best reflected in the Rideshare Passenger cost estimate, which is the incremental cost of an additional passenger.

Table 6-5 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 31.1¢, and each passenger-mile shifted from an Average Car to a Rideshare Passenger provides about 53¢ in external savings.

Table 6-5 **External Savings Due To Travel Shifts** (Per Passenger-Mile)

	Peak Shifting	Compact Car	Electric Car	Rideshare Passenger	Diesel Bus	Electric Trolley	Bicycle	Walk	Telework
Urban Peak	$0.311	$0.031	$0.054	$0.530	$0.239	$0.214	$0.511	$0.524	$0.458
Urban Off-Peak	$0.000	$0.017	$0.033	$0.218	-$0.119	-$0.120	$0.213	$0.215	$0.147
Rural	$0.000	$0.013	$0.015	$0.130	-$0.220	-$0.195	$0.127	$0.129	$0.094
Average	$0.062	$0.018	$0.030	$0.245	-$0.088	-$0.083	$0.238	$0.242	$0.188

This table indicates the estimated external cost savings (reductions in congestion, parking, roadway costs, etc.) due to a shift from Average Car travel to another mode.

[3] Todd Litman, *Evaluating Public Transit Benefits and Costs*, Victoria Transport Policy Institute (www.vtpi.org), 2002.

Total Transportation Costs

Table 6-6 shows estimated U.S. motor vehicle travel costs based on this analysis.

Table 6-6 **Motor Vehicle Costs, by Mile and Total** (1996)

	Mileage	Internal Costs		External Costs		Total Costs	
	(billions)	Per Mile	Total (billions)	Per Mile	Total[4] (billions)	Per Mile	Total (billions)
Urban Peak	460	$0.71	$327	$0.59	$270	$1.30	$597
Urban Off-Peak	920	$0.71	$657	$0.33	$305	$1.05	$962
Rural	920	$0.64	$589	$0.20	$180	$0.84	$769
Total	*2,300*	*$0.68*	*$1,573*	*$0.33*	*$755*	*$1.01*	*$2,328*

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

That internal costs per vehicle mile are the same for Urban Peak and Urban Off-Peak travel ($0.71 per mile) is unexpected, since the stop-and-go driving of peak period traffic increases travel time, stress and vehicle operating costs. However, this is offset by lower vehicle occupancy rates (1.1 average passengers) compared with off-peak travel (1.6 average), resulting in higher travel time and crash costs per vehicle-mile for off-peak and rural travel.

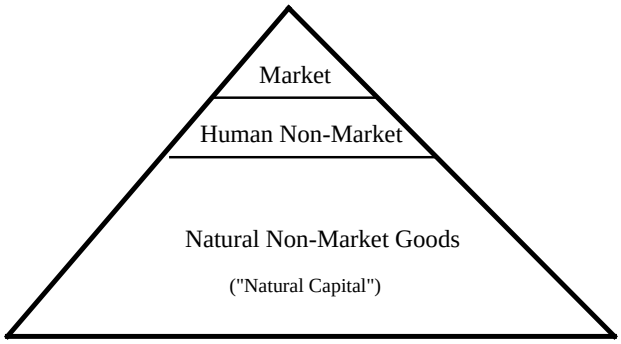
This total of $2.3 trillion, which equals over 40% the U.S. Gross National Product (GNP), may seem to be an unreasonably high cost for transportation, especially since it includes only roadway modes. The explanation is that a major portion of these costs are non-market, including personal time, crash risk, and environmental degradation. Only six of the twenty cost categories in this study are direct market costs (although the non-market costs impose significant indirect market costs such as medical care and disability costs from crashes and pollution). Thus, the majority of these costs are excluded from standard GNP calculations.

The market economy can be imagined as the tip of a pyramid above the non-market human economy (unpaid travel time, housework, childcare, and volunteer activities that contribute to society), that is based on the foundation provided by the non-market natural economy, which provides clean air, water, and beauty, plus marketed natural resources (Figure 6-8).[5] Our total endowment of wealth, including non-market goods, is much larger than just market activities. We are richer than indicated by just our financial assets due to these non-market goods. Non-market costs, such as crash risk, personal time, and environmental degradation, represent the loss of non-market resources to ourselves, to other members of society, and to future generations. These estimates indicate what it would cost if the non-market goods consumed by transport required compensation.

[4] 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.

[5] Robert Costanza, et al., "The Value of the World's Ecosystem Services and Natural Capital," *Nature*, Vol. 387, 15 May 1997, pp. 253-260.

Figure 6-8 **Market, Human Non-Market, and Natural Non-Market Goods**

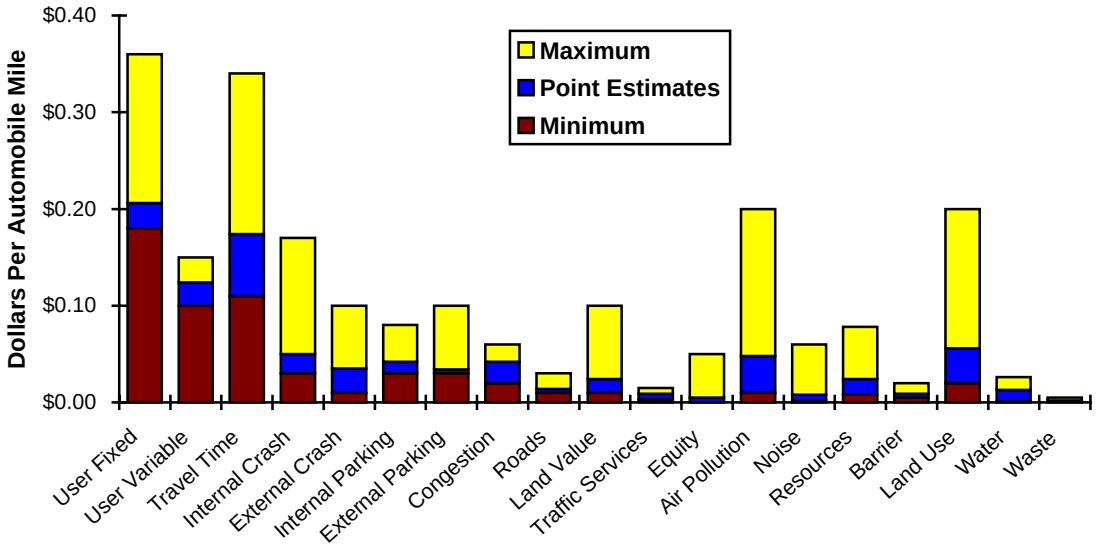


Markets represent only a small portion of all human benefits. A larger portion of benefits are provided by human non-market and natural non-market goods (sometimes called "natural capital"). Many of the costs of transportation represent losses of these goods.

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 6-9 illustrates the Minimum and Maximum estimates provided for each cost.

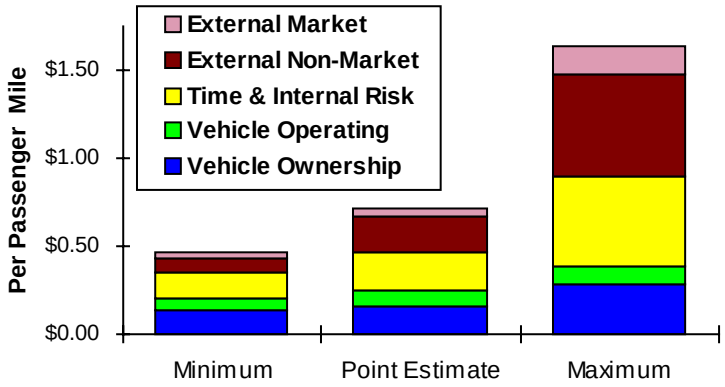
Figure 6-9 **Ranges of Average Automobile Costs**



This graph shows the most likely range for each cost.

Figure 6-10 shows the totals of 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 transportation decisions.

Figure 6-10 **Ranges of Average Automobile Costs by Major Category**



This graph compares cost range by major categories.

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. 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 6-7 shows the survey results. These indicate that the public considers social and environmental transportation costs significant. Even the lowest ranking cost, *Ugliness of roads*, has a value indicating that respondents, on average, considers it between "Not Very Serious" and "Somewhat Serious." 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 6-7 **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 6-8). "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.

Table 6-8 **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.

Conclusions

If you ask people what it costs to drive they typically mention vehicle operating expenses, which average approximately 12¢ per mile for a typical automobile. Some may also include some vehicle ownership costs, which averages about 21¢ 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 $0.84 per vehicle mile for rural driving to $1.30 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 6-9 illustrates the estimated net external cost savings that result when an 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. 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 6-9 **Daily External Savings Due To Commute Mode Shifts**

Peak Shifting	Compact Car	Electric Car	Rideshare Passenger	Diesel Bus	Electric Trolley	Bicycle	Walk	Telework
$6.23	$0.62	$1.07	$10.59	$4.78	$4.29	$10.21	$10.47	$9.15

This table indicates the estimated external cost savings (reductions in congestion, parking, roadway costs, etc.) due to a shift from Average Car travel to another mode for a typical 20-mile round trip urban commute.

Some of these 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 the lowest reasonable estimates, external costs are significant compared with the magnitude of costs that are normally recognized in transportation decision making.