10. Applications and Case Studies

The cost and elasticity estimates developed in this study are applied in this chapter to representative examples of transportation decision making.

Chapter Index

10.1 Evaluating Transportation Demand Management (TDM) Savings

Many communities have programs that encourage mode shifting. The Oil-Smart Commute Performance Test examines the benefits of such a program. The Oil-Smart campaign, an annual program spearheaded by the Seattle based Bullitt Foundation, encourages residents to use efficient travel modes. Hundreds of people participate. During four days in March 1994, 62 trips were monitored for a Commute Performance Test to determine the benefits of changing travel patterns. Of these trips, about half consisted of two links, such as walking to a park-and-ride lot to catch a vanpool, so 92 total links were analyzed. Table 10.1-1 summarizes the distances, times, costs and savings for one day's trips from Capitol Hill to the Pioneer Square area.

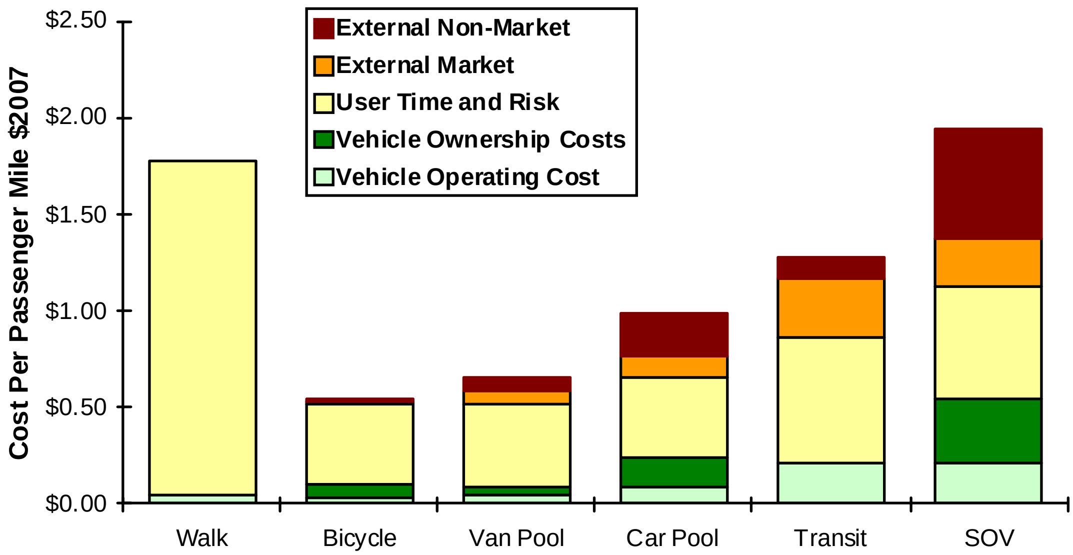
Table 10.2-1 **Capitol Hill to Pioneer Square Trip Summary** (Urban-Peak 2007 USD)

	Mode	Dist-ance	Travel Time	Internal Cost	External Cost	Total Cost	Savings Over SOV
		miles	minutes	per trip	per trip	per trip	per day
1	Walk	2.2	41	$3.64	$0.01	$3.66	$6.05
2	Bike	2.75	10	$1.27	$0.08	$1.35	$10.65
3	Bike	3.5	16	$1.89	$0.11	$1.99	$9.37
4	Van Pool Driver	2.7	18	$3.95	$0.37	$4.32	$4.71
5	Van Pool Passenger	2.7	18	$2.57	$0.38	$2.96	$7.43
6	Van Pool Passenger, Walk	2.8	24	$3.04	$0.38	$3.41	$7.93
7	Van Pool Passenger, Walk	2.8	24	$3.04	$0.38	$3.41	$7.93
8	Van Pool Passenger, Walk	2.8	24	$3.04	$0.38	$3.41	$7.93
9	Van Pool Passenger, Walk	2.8	24	$3.04	$0.38	$3.41	$7.93
10	Bus Rider, Walk	3.2	35	$5.17	$1.27	$6.44	$0.46
11	Bus Rider, Walk	2.5	30	$4.82	$1.12	$5.94	$1.48
12	Car Pool Driver	3.4	15	$3.71	$0.81	$4.51	$4.33
13	Car Pool Passenger, Walk	3.3	20	$2.89	$0.82	$3.71	$5.93
14	Car Pool Passenger, Walk	3.3	20	$2.89	$0.82	$3.71	$5.93
15	SOV Driver	3.4	10	$3.96	$2.72	$6.68	$0.00
	Totals	*44.15*	*329*	*$48.91*	*$9.98*	*$58.89*	*$88.07*

This table illustrates one of four Commute Performance Test days. Savings compared with an SOV trip are doubled to estimate daily savings.

Shifts to alternative modes provide especially significant reductions in *external* costs. For example, the calculated external cost of a trip from Capitol Hill to Pioneer Square is about $2.60 for an SOV driver, but averages only $0.50 for other modes. If all 15 round trips that day were made by SOV, the total external cost would have increased from about $20 to $80. Figure 10.1-1 shows these by major cost categories.

Figure 10.1-1 **Major Cost Categories per Mile by Mode**



This graph compares average travel costs per passenger mile for six modes used in the 1994 Oil Smart Commute Performance Test.

Significant Findings:

- Total savings were $616 compared with the same trips made entirely by SOV. This averages about $11 daily savings per capita.
- External costs of SOV travel average about 5 times greater per trip than other modes.
- The greatest savings *per trip* resulted from vanpool riders who did not drive to their vanpool stop. Total costs of van pool, car pool, and transit trips were sensitive to how the traveler got to their transit stop or rideshare meeting place.
- The greatest savings *per mile* resulted from bicyclists, since they had low operating and external costs but travel faster than pedestrians. The costs of bicycle and pedestrian trips are sensitive to the time value assigned to travel.

These findings indicate that significant investments in Transportation Demand Management programs are justified for programs that encourage use of alternative modes and reduce automobile use. They also indicate which modes and trip combinations offer the greatest total savings and the greatest potential for reducing external costs. Note that this does not account for the economies of scale that could be obtained by substantial mode shifts to transit.

10.2 Price Impacts on User Travel Decisions

Motor vehicle travel has increased both absolutely and per capita. This growth is sometimes cited as evidence of "America's love affair with the automobile," but an alternative explanation is that low prices simply make driving too attractive for other modes to compete. As indicated in Chapter 4, the immediate out of pocket cost of driving is typically lower per mile than bus fares. Studies described in Section 5.2 show that transport prices significantly affect travel patterns. *Low priced driving supports a cycle of increased automobile use, automobile ownership and automobile dependency.*

Consider the impacts of different transport prices (defined as the *perceived variable internal cost*, which includes user non-market costs such as travel time and risk) on typical shopping trips.[1] Assume a resident has three shopping options: a local store accessible by a 1/2-mile walk, a small supermarket 2 miles away where prices average 15% lower than the local store, and a megastore 7.5 miles away where prices average 30% lower than the local store.

The current variable price of Urban Off-Peak driving is $0.41 per vehicle mile, which includes vehicle operating costs, travel time, and internal risk. The *total* cost of driving, including fixed and external costs, averages $1.20 per mile. Since walking has minimal external costs, both price and total cost are $1.39 per mile. Including health benefits brings the cost down to $0.91. Table 10.2-1 compares the shopping expenditure that would justify traveling to a more distant store, based on current and full-cost pricing.

Table 10.2-1 **Current Variable and Total-Cost Travel Price Impact on Store Selection**

	Local Store	Local Supermarket	Megastore
Round Trip	1 mile walk	4 mile drive	15 mile drive
Savings over Local Store.	$0	15%	30%
Current trip price.	1 x 1.15 = $1.15	4 x 0.41 = $1.64	15 x 0.41 = $6.15
Current travel price premium over Local Store.	$0	1.64-1.15= 0.49	6.15-1.15=$5.00
Current shopping total to justify longer trip.	$0	0.49/15% = $3.27	5.00/30% = $16.67
Full trip cost.	1 x $0.91 = $0.91	4 x $1.20 = $4.80	15 x 1.20 = $18.00
Full-cost travel price premium over Local Store	$0	$4.80-0.91=$3.89	$18.00-0.91=$17.09
Full-cost shopping total to justify longer trip.	$0	$4.80/15% = $32.00	$17.09/30%=$56.97

This table shows how underpricing discourages use of local services.

Because driving is underpriced, users have little financial incentive to walk 1/2 mile to a local store, or shop at a local supermarket. At $0.41 per mile, the price of driving to a store 2 miles away appears almost the same as the price of walking to a store 1/2 mile away, and even a purchase under $20 justifies the 15 mile Megastore trip. But when *all* costs are considered the shorter trips become more attractive, and the Megastore is only justified for purchases over $57. This illustrates how prices that are below total costs skew user decisions to make longer and more frequent automobile trips.

[1] Jean-Marie Beauvais (2008), *Setting Up Superstores and Climate Change*, Beauvais Consulting; at www.vtpi.org/superstores.pdf.

Of course, other factors affect shopping habits. It can be difficult to carry big shopping loads without a car (although easier with a wagon or bicycle trailer), and large stores have a wider selection of goods. On the other hand, walking and shopping at local stores offers health, enjoyment and community contact benefits. Shopping is often part of linked trips, which reduces per trip costs, but linked trips tend to occur during peak periods when congestion and travel time values are high. This analysis indicates that a portion of the savings that individuals enjoy by shopping at a large, central store are offset by incremental external transport costs, and the discrepancy between user price and total costs affects many travel decisions.

Some economists argue that transport costs should be considered when calculating maximum mortgage payments.[2] Currently, the increased travel expenses associated with an automobile dependent home are not considered a cost by most lending agencies. As a result of underpriced driving and the omission of transportation expenses in mortgage budget analysis, home selection decisions are skewed toward automobile dependent, high travel cost houses, resulting in greater internal and external costs.

Table 10.2-2 evaluates transportation cost impacts on home location decisions. The Central Home reduces *external* costs by about $4,900 annually compared with the Exurban Home, with a capitalized value of approximately $50,000 (the additional housing value that could be purchased if savings were invested in the mortgage). This implies that underpriced driving underprices exurban housing by this amount. The Central Home saves $10,852 annually in *total* driving costs over an Exurban Home, worth over $100,000 in capital value if used for mortgage payments.

Table 10.2-2 **Current and Total-Cost Travel Price Impact on Home Selection**[3]

	Exurban Home	Central Home	Savings
Cars owned.	2	1	1
Annual Household VMT.	25,000	12,500	12,500
Annual user costs.	$11,880	$5,940	$5,940
Annual external costs.[4]	$11,237	$6,325	$4,912
Total costs.	$23,117	$12,265	$10,852

Many decisions, including where to live, involve a tradeoff between travel costs and potential benefits. The more travel is underpriced the more automobile dependant land use, and resulting automobile travel, can be expected.

[2] Institute for Location Efficiency (www.locationefficiency.com); VTPI (2008), "Location Efficient Development," *Online TDM Encyclopedia*, VTPI (www.vtpi.org/tdm/tdm22.htm).
[3] John Holtzclaw (1990), "Explaining Urban Density and Transit Impacts on Auto Use," NRDC (www.nrdc.org).
[4] This assumes that Central vehicles are driven 33% Urban Peak, 33% Urban Off-Peak, and 33% Rural, Exurban vehicles are driven 23% Urban Peak, 33% Urban Off-Peak and 44% rural, and this driving incurs external costs of $0.61, $0.34 and $0.20 per mile respectively, as calculated in the previous version of this report and updated to 2007 dollars by CPI.

10.3 Marginalizing User Costs

Marginalizing costs could allow automobile owners who reduce their driving to enjoy savings currently unavailable.[5] Various versions of this concept have been advocated by environmental and consumer organizations.[6] The following example based on the previous version of this study is expressed in 1996 dollars and is based on lower than current total mileage; present savings would be considerably greater.

Automobile owners typically pay approximately 21¢ per mile in fixed costs and 13¢ per mile in variable costs to drive. Fixed costs include about 8¢ per mile in vehicle insurance, licenses, registration, and vehicle ownership taxes, totaling about $1,000 per year.[7] Table 10.3-1 shows the effect of an 8¢ per mile increase in vehicle operating costs.

Table 10.3-1 **Estimated Annual VMT Impact of Marginalizing User Costs** (1996 USD)[8]

	Units	Urban Peak	Urban Off-Peak	Rural	Totals
Current Vehicle Operating Cost	$ per mile	0.15	0.13	0.11	
Current VMT	billions	460	920	920	2,300
Revised Price (+$0.08/mile)	per mile	0.23	0.21	0.19	
1-10 Year Elasticity		-0.2	-0.2	-0.2	
1-10 Year Revised VMT	billions	400	806	813	2,019

Changing insurance, registration, licensing, and taxes into variable costs would reduce overall driving at no extra cost to users, increasing overall transportation efficiency.

The estimated 281 billion miles per year foregone represents low value driving that users would forgo rather than pay an extra 8¢ per mile. Marginalizing these costs provides benefits to users (who enjoy savings not currently available) and society from reduced external costs. Table 10.3-2 shows the potential savings from this price change.

Table 10.3-2 **Savings of Reduced Driving from Marginalizing User Costs** (1996 USD)[9]

	Units	Urban Peak	Urban Off-Peak	Rural	Totals
Travel Reduction	billion VMT	60	114	107	281
Internal Saving	$/mile	0.71	0.71	0.64	
Total Internal Saving	$billions	$43	$81	$69	$193
External Savings	$/mile	0.61	0.34	0.20	
Total External Savings	$billions	$37	$39	$21	$97
Total Savings	*$billions*	*$80*	*$120*	*$90*	*$290*

Marginalizing costs that are currently fixed could save over $290 billion annually.

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[5] Vehicle owners who currently reduce their driving by 100 miles only save about $13.00. By marginalizing these costs the same 100 mile reduction in driving would save $21.00.

[6] VTPI (2008), "Pay As You Drive Vehicle Insurance," *Online TDM Encyclopedia*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tdm/tdm79.htm

[7] Jack Faucett Associates (1992), *Costs of Owning and Operating Automobiles, Vans and Light Trucks*, FHWA (www.fhwa.dot.gov).

[8] VTPI (2008) "Transportation Elasticities," *Online TDM Encyclopedia*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tdm/tdm11.htm

[9] Assumes user savings proportional to reduced driving.

Table 10.3-2 analysis oversimplifies actual travel cost savings. In practice, some reduced automobile costs would be offset by increases in other types of travel. Table 10.3-3 recalculates the savings assuming that VMT reductions result 1/3 from reduced trips, 1/3 from reduced trip length, and 1/3 from mode shifts that are distributed equally among van pools, car pools, bus, bicycling, walking, and telecommuting. This more accurate analysis shows lower savings than in Table 10.4-2, but still worth over $200 billion annually.

Table 10-3.3 **Accurate Savings of Reduced Driving from Marginalizing Costs** (1996 USD)

	Units	Urban Peak	Urban Off-Peak	Rural	Totals
Eliminated Trips	billion VMT	20	38	36	192
Internal Savings	$/mile	$0.71	$0.71	$0.64	
Total Internal Savings	$billions	$14	$27	$23	$64
External Savings	$/mile	$0.61	$0.34	$0.20	
Total External Savings	$billions	$12	$13	$7	$31
Total Savings	*$billions*	*$26*	*$40*	*$30*	*$96*
Shortened Trips[10]	billion VMT	20	38	36	94
Internal Savings	$/mile	$0.47	$0.47	$0.41	
Total Internal Savings	$billions	$9	$18	$15	$42
External Savings	$/mile	$0.49	$0.30	$0.18	
Total External Savings	$billions	$10	$11	$6	$27
Total Savings	*$billions*	*$21*	*$31*	*$22*	*$74*
Shift to each of Six Modes	billion VMT	3	6	6	
Internal & External Savings[11]	$/mile	Varies	Varies	Varies	
Total Internal Savings	$billions	$5	$11	$8	$24
Total External Savings	$billions	$10	$8	$1	$19
Total Savings	*$billions*	*$15*	*$19*	*$9*	*$43*
Total VMT Reduction	billions	60	114	107	281
Total Internal Saving	$billions	$28	$56	$46	$130
Total External Savings	$billions	$32	$32	$14	$78
Total Savings	*$billions*	*$60*	*$88*	*$60*	*$208*

This analysis, more accurate than Table 10.4-2, shows annual savings over $200 billion.

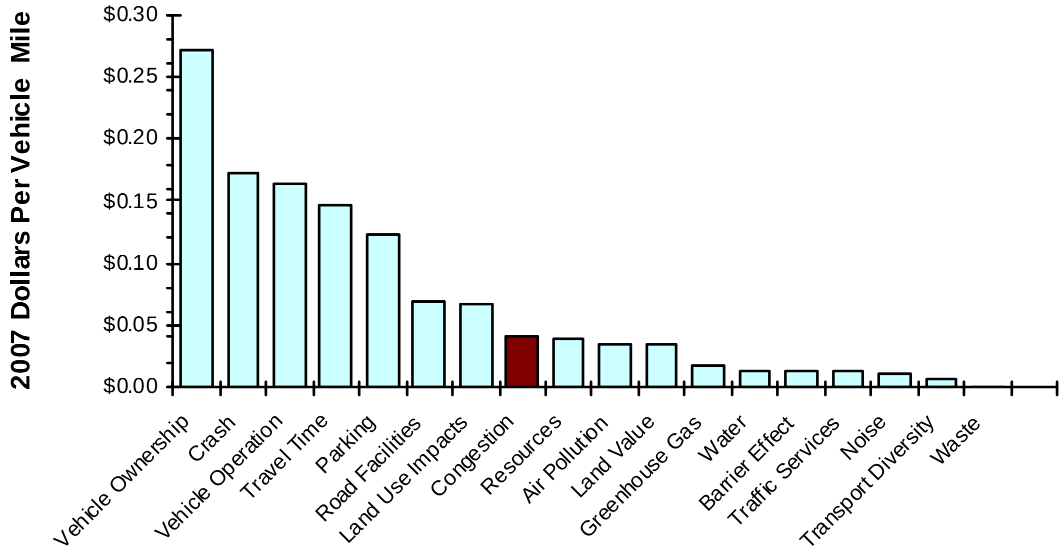
Another way to marginalize user costs is to "Cash Out" free parking.[12] This offers employees who currently receive parking subsidies the option of receiving cash instead. This benefits employers by reducing parking costs and gives a financial bonus to emplolyees who use alternative modes. The combination of marginalizing automobile insurance and registration, and Cashing Out employee parking could reduce current driving about 15%, providing many billions of dollars in savings to users and society. The foregone trips represent low value travel that automobile users are willing to eliminate given greater choice.

[10] Internal savings include user variable costs. External savings are all external costs except parking.
[11] Calculated in a separate spreadsheet.
[12] VTPI (2008), "Commuter Financial Incentives," *Online TDM Encyclopedia*, (www.vtpi.org/tdm/tdm9.htm)

10.4 Evaluating Congestion Reduction

Although congestion reduction often dominates transportation planning goals, our comprehensive analysis indicates that overall it is only a middle-range cost, as shown in Figure 10.4-1. Traffic congestion is a relatively small cost compared with the total of costs that typically increase in response to efforts to accommodate more vehicle traffic.

Figure 10.4-1 **Average Automobile Costs Ranked by Magnitude**



Congestion is overall a moderate cost.

Since travel time is a high ranking cost, it could be argued that projects that increase travel speeds offer significant potential benefits. However, as discussed in Section 5.4, people tend to maintain a constant travel time budget, so the benefits of increased travel speeds translate into more and longer trips, and shifts in activity locations, called *generated traffic* (the additional peak-period travel on the improved route, including shifts in time and route) and *induced vehicle travel* (absolute increases in total per capita vehicle mileage).[13] Most highway investment analyses compare construction financial costs against long-term congeston reduction benefits, primarily travel time and vehicle operating cost savings. However, it is accurate to compare short-term congestion financial costs and time delays (due to construction) *plus* long term incremental cost increases from induced travel, against medium-term congestion reduction benefits.

Table 10.4-1 compares the costs typically reduced and increased with highway expansion. Conventional project economic evaluation considers a limited set of costs (italicized). Many of the costs that tend to increase with induced travel are overlooked. As a result, conventional evaluation tends to exaggerate highway expansion benefits, and therefore undervalues alternative congestion reduction solutions such as pricing reforms, grade separated HOV and transit routes, and commute trip reduction programs.

[13] Todd Litman (2001), "Generated Traffic; Implications for Transport Planning," *ITE Journal* (www.ite.org), Vol. 71, No. 4, April, pp. 38-47; at www.vtpi.org/gentraf.pdf.

Table 10.4-1 **Transportation Costs Affected by Increased Roadway Capacity**

Costs Reduced in the Medium Term by Roadway Expansion	Costs Increased Over the Long Term by Road Expansion		
	Vehicle Costs	Parking	*Road Facilities*
Congestion delays	*Accidents*	*Air Pollution*	Resource Externalities
Vehicle Operating Costs	Waste Disposal	Barrier Effect	Municipal Services
User Travel Time	Land Use Impacts	Water Pollution	Roadway Land
	Noise	Diveristy/Equity	Climate Change

Increasing roadway capacity reduces 3 costs, but increases 15 others over the long term.

Current road pricing and planning practices lead to overinvestment in both money and urban land in roads and parking facilities.[14] Empirical evidence indicates that traffic congestion imposes a relatively minor constraint to economic activity: cities such as Hong Kong, Tokyo, New York, London and Paris, have intense traffic congestion yet are economically successful. Although traffic congestion is clearly an economic cost, it does not appear to be a significant burden if people have alternative access options such as grade separated public transit and neighborhood stores.

Conventional transportation project evaluation model results are significantly affected by the consideration of generated traffic.[15] Incorporating generated traffic reduces projected highway expansion benefits and increased the net projected benefits of No Build, Light Rail, and Road Pricing options. External costs were not incorporated in this analysis; doing so would certainly increase the calculated costs and decrease the benefits associated with projects that add roadway capacity. Williams and Lam reached similar conclusions, and point out that highway investments can impose external costs in terms of reduced transit service efficiency.[16]

Framing the Congestion Cost Question
If you ask people, *"Do you think that traffic congestion is a significant problem that deserves significant investment?"* most would probably answer yes. If you ask them, *"Would you rather invest in road capacity expansion or use lifestyle changes, such as increased urban density and more use of walking, bicycling, car pooling and public transit to solve congestion problems?"* a smaller majority would probably choose the road improvement option. These are essentially how choices are framed by conventional transportation plans. But if you presented a more realistic description of choices by asking, *"Would you rather spend a lot of money increasing road capacity to achieve only moderate and temporary reductions in traffic congestion, and deal with increase personal, municipal, social and environmental costs from increased motor vehicle traffic, or would you rather create a more diverse transportation system to avoid such problems?"* the preference for road building would probably disappear.

[14] Takahiro Miyao and Yoshitsugu Kanemoto (1987), *Urban Dynamics and Urban Externalities*, Harwood Academic Publishers (NY), pp. 77-87.
[15] Robert Johnston and Raju Ceerla (1996), "The Effects of New High-Occupancy Vehicle Lanes on Travel and Emissions," *Transportation Research*, Vo. 30A, No. 1, pp. 35-50.
[16] H.C.W.L. Williams and W.M. Lam (1991), "Transport Policy Appraisal With Equilibrium Models I: Generated Traffic and Highway Investment Benefits," *Transport. Research B*, Vol. 28 No. 5, pp. 253-279.

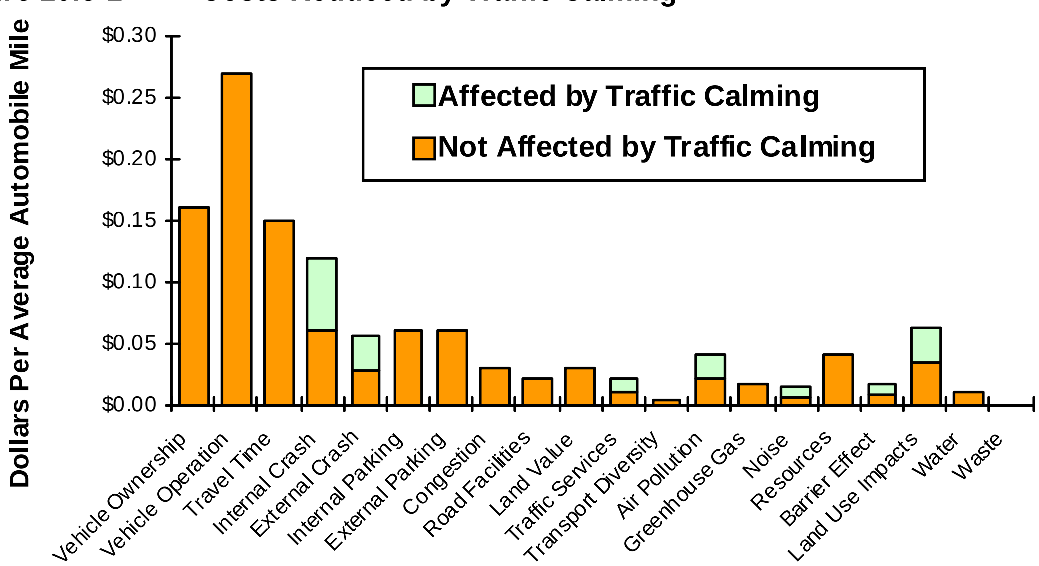
10.5 Evaluating Traffic Calming and Traffic Management Options[17]

A conflict often exists between different roadway design features. Designs that maximize motor vehicle traffic volumes and speeds increase:

- Land requirements for streets and parking.
- Risk of accidents between automobiles and other road users.
- Barriers to pedestrian and bicycle movement.
- Noise, air pollution and dust.
- Petroleum depletion and global warming.
- Automobile dependency and urban sprawl.

Figure 10.5-1 illustrates estimated costs likely to decline due to traffic calming and other traffic management strategies, assuming that the same amount of driving takes place but at lower speeds.[18] This analysis indicates that local environmental and social costs are significant compared with other transport costs.[19] Current roadway evaluation practices ignore many of these impacts, skewing road design to favor vehicle traffic at the expense of local environmental objectives and alternative modes.

Figure 10.5-1 **Costs Reduced by Traffic Calming**



A number of motor vehicle costs can be reduced by traffic calming.

17 VTPI (2008), "Traffic Calming," Online TDM Encyclopedia, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/tdm/tdm4.htm

18 Based on an average of Urban Peak and Off-Peak costs, with noise and barrier effect costs doubled to represent higher impacts on neighborhood streets.

19 This does not include additional long term benefits resulting from reducing automobile dependency.

10.6 Evaluating Electric Vehicle Benefits

Alternative fuels, especially electric vehicles, are often cited as solutions to transportation pollution problems. The costs developed in this report can be used to evaluate these options from an overall economic perspective. This analysis focuses on electric vehicles, although a similar analysis could be performed for other fuels.

Table 10.6-1 summarizes how various cost categories are affected by changing from petroleum to electric propulsion. A number of costs are reduced, although none are eliminated by electric vehicles. In particular, tailpipe air pollution is shifted to electrical generation facilities, and engine noise is reduced, although tire noise is not.

Table 10.6-1 **Fuel Type Effects on Transportation Costs**

Costs Typically Reduced in Electric Vehicles	Costs Unaffected by Electric Vehicles		Costs Typically Increased in Electric Vehicles
Air pollution	User travel time	Congestion	Vehicle ownership
Greenhouse Gas Emissions	Crashes	Parking	Vehicle operation
Noise	Land value	Barrier effect	Road facilities[20]
Water pollution	Transport Diversity	Land use impacts	Waste (from batteries)
Resource externalities (energy)	Traffic services		

This table shows how costs typically differ between gasoline and electric vehicles.

Three types of electric vehicles are considered:

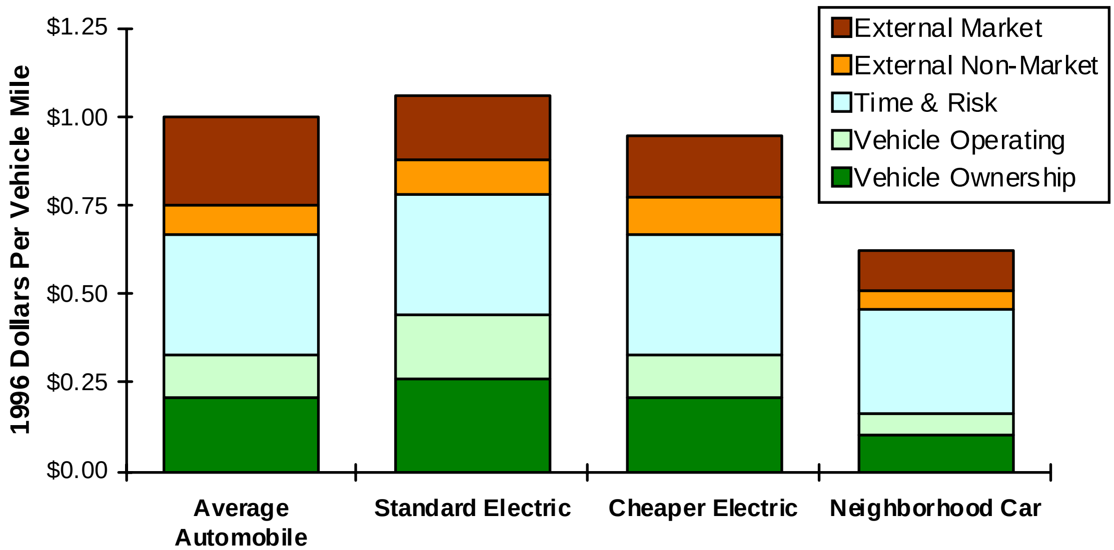
1. *Standard Electric.* This is based on current electric car ownership and operating costs, which are higher than a standard automobile. This uses the electric vehicle costs defined earlier in this report.
2. *Cheaper Electric.* This assumes that electric car costs will decline in the near future due to increased production. Ownership and operating costs are equal that of an average automobile, and other costs are as defined earlier for an electric vehicle.
3. *Neighborhood Vehicle.* These are small, inexpensive, low power, low speed electric vehicles intended for local urban travel.[21] These are estimated to reduce all costs except travel time, congestion, and road services (policing, planning, etc.) by 50%.[22]

Figure 10.6-1 shows the total costs of these four vehicles by major category. Although Standard Electric cars reduce some non-market externalities, their current high ownership and operating costs make them slightly more expensive overall. Of course, these average values underestimate the cost differential in urban areas where noise and local air

[20] Although road facility costs do not actually increase, electric vehicle use does not contribute to dedicated fuel taxes, so their subsidy is greater based on the cost analysis framework used in this report.
[21] Daniel Sperling (1995), "Prospects for Neighborhood Electric Vehicles," *Transportation Research Record 1444* (www.trb.org), p. 16-22.
[22] This estimate is somewhat arbitrary since specific performance and cost data are not available.

pollution costs are relatively high.[23] Assuming that reduced future production costs will make Cheaper Electric cars available, overall savings are possible. However, electric cars do not reduce many external costs of driving, including parking subsidies, accident risk, urban sprawl, or inequity. To significantly reduce total costs requires an inexpensive, efficient, safe, small vehicle that does not encourage urban sprawl, such as the Neighborhood Car.

Figure 10.6-1 **Electric Vehicle Cost Comparison by Major Category**



This graph compares cost categories of three electric vehicles and an average automobile based on the assumptions stated above. Data is based on the previous version of this study and presented in 1996 dollars.

[23] Roland Hwang, et al. (1994), *Driving Out Pollution: The Benefits of Electric Vehicles*, Union of Concerned Scientists (www.ucsusa.org). Estimated electric vehicle lifecycle benefits are $17,570 in So. California.