

## Mobility Management As A Traffic Safety Strategy

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### ABSTRACT

This paper investigates the traffic safety impacts of *mobility management* (also called *transportation demand management* or *TDM*), which consists of various strategies that affect travel patterns. All else being equal, vehicle mileage reductions reduce crashes, although the safety impacts of a particular mobility management program vary depending on travel changes and travel conditions. The safety impacts of mode shifting depends on the relative risk borne and imposed by each mode. Shifting vehicle travel from congested roads to less-congested conditions tends to reduce crashes but increases crash severity. Strategies that reduce trip distance and traffic speed can provide significant safety benefits. Safety evaluation of mobility management is affected by how crashes are measured: *per-mile* analysis tends to ignore mileage as a risk factor and the potential traffic safety benefits of mileage reductions, while *per capita* analysis indicates that mileage reductions provide significant safety benefits. This analysis suggests that mobility management can be a cost effective traffic safety strategy, and increased safety is one of the largest potential benefits of mobility management. More research is needed to better predict the traffic safety impacts of a particular mobility management program.

## INTRODUCTION

*Mobility management (transportation demand management or TDM)* includes various strategies that help achieve transport improvement objectives by changing trip frequency, destination, mode and timing. Table 1 lists various mobility management strategies. Mobility management is an increasingly common response to urban traffic congestion and pollution problems. For example, the US Congestion Management and Air Quality (CMAQ) program and many regional transportation plans include mobility management components. Mobility management is implemented primarily to reduce traffic congestion and pollution emissions, but it can also significant traffic safety impacts.

Table 1 Mobility Management Strategies (VTPI, 2002)

<b>Improves Transport Options</b>	<b>Pricing Incentives</b>	<b>Land Use Management</b>	<b>Implementation Programs</b>
Transit improvements	Congestion pricing	Smart growth	Commuter trip reduction programs
Walking improvements	Distance-based fees	New urbanism	School and campus transport management
Cycling improvements	Employee transportation benefits	Location-efficient development	Freight transport management
Rideshare programs	Parking cash out	Parking management	Tourist transport management
Flextime	Parking pricing	Transit oriented development	Transit marketing
Compressed workweek	Pay-as-you-drive vehicle insurance	Car free planning	Nonmotorized encouragement
Car sharing	Fuel tax increases	Traffic calming	
Telework			
Taxi improvements			
Bike/transit integration			
Guaranteed ride home			

*This table lists various mobility management strategies.*

This article explores the effects mobility management can have on traffic safety. It is both a conceptual paper and an attempt to critically synthesize relevant empirical studies. It examines the travel impacts of mobility management, surveys available research on the relationships between travel changes and traffic crashes, and investigates the degree to which current transport decision-making takes safety impacts into account when evaluating planning decisions that affect total vehicle mileage.

This issue can be considered both simple and complex. It is simple because vehicle-mileage undoubtedly affects crash frequency. All else being equal, planning decision that increase vehicle mileage can be expected to increase total crashes, and strategies that reduce mileage tend to reduce total crashes.

However, it is complex because mobility management strategies have various travel impacts (Table 2), which have various impacts on crash risk. Different mobility management programs tend to affect different types of travelers and trips, such as commute trips or short-distance urban trips, which have different risk profiles. It is therefore important to understand the travel impacts of different mobility management strategies, and the risks associated with different types of travel.

Table 2 Examples of TDM Travel Impacts

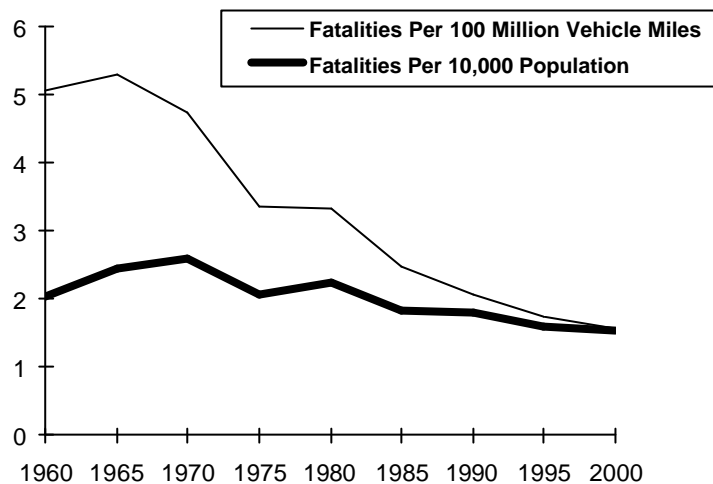
TDM Strategies	Mechanism	Travel Changes
Commuter trip reduction	Improve commuter travel options, encourages use of alternative modes.	Reduced peak-period automobile trips, shifts to alternative modes, shifts in commute travel timing.
Flextime	Improved transport choice.	Shifts travel time (when trips occurs).
Compressed workweek	Improved transport choice.	Reduces commuter trips.
Road pricing	Pricing	Shifts travel time, reduces vehicle travel on a particular roadway.
Distance-based charges	Pricing	Reduces overall vehicle travel.
Transit improvements	Improved transport choice.	Shifts mode, increases transit use.
Rideshare promotion	Improved transport choice.	Increases vehicle occupancy, reduces vehicle trips.
Pedestrian and bicycle improvements	Improved transport choice, facility improvements.	Shifts mode, increases walking and cycling.
Telework	Electronic communication substitutes for physical travel.	Reduced vehicle travel for commuting and other activities.
Carsharing	Improved transport choice.	Reduces vehicle ownership and trips.
Smart Growth, New Urbanism	More efficient land use, improved travel choices.	Shifts mode, reduces vehicle ownership and trip distances.
Traffic Calming	Roadway redesign.	Reduces traffic speeds, improves pedestrian conditions.

*Different types of TDM strategies cause different types of travel changes.*

## EVALUATING CRASH RISK

In order to evaluate mobility management safety impacts it is important to consider how crash risks are measured. Figure 1 illustrates U.S. traffic fatality rates between 1960 and 2000 using two different denominators in the risk calculations. These indicators provide two very different conclusions concerning the magnitude of traffic risk and how traffic safety can be improved (Wilde, 1984).

Figure 1 U.S. Traffic Fatalities (BTS, 2000)



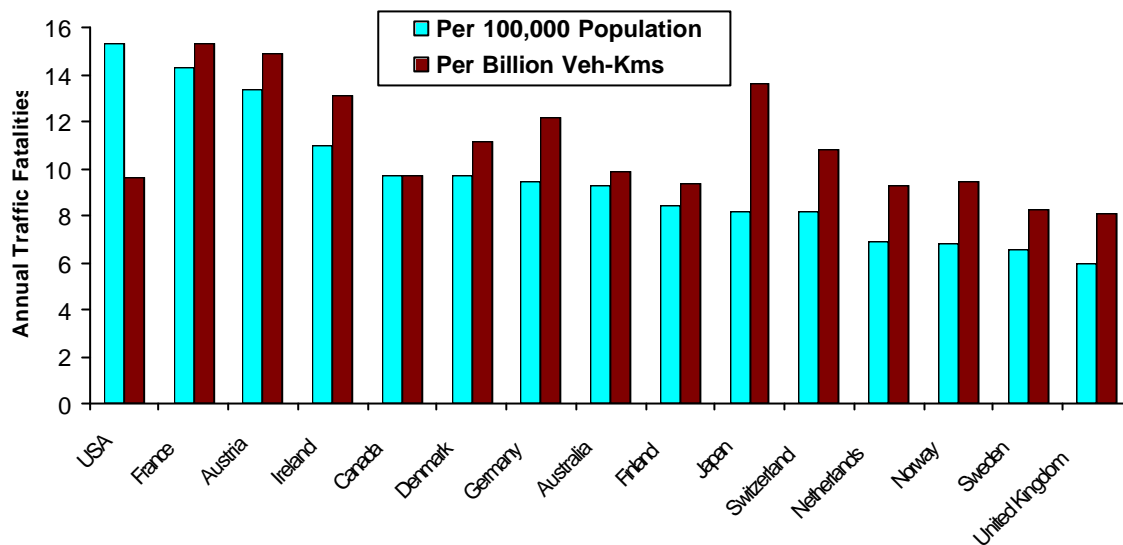
*This figure illustrates traffic fatality trends over four decades. When crashes are measured per vehicle mile, they decline significantly, but when measured per capita they show relatively little decline due to increased per capita vehicle mileage over this time period.*

Transportation professionals often evaluate road risk based on crash and fatality rates *per unit of vehicle travel* (e.g., per hundred million vehicle -miles or kilometers). Measured in this way, fatality rates declined by more than two thirds during the last four decades. From this perspective, current traffic safety programs are successful and the best way to reduce road risk further is to continue applying the strategies that worked so well in the past.

But per capita vehicle mileage has more than doubled in the U.S. over the last forty years, offsetting much of the decline in per-mile fatality rates. When measured *per capita* (e.g., per 10,000 population), as with other health risks, there has been surprisingly little improvement during this period despite large investments in safer roads and vehicles, increased use of occupant safety devices, significant reductions in drunk driving, and improvements in emergency response and trauma care. Taking these factors into account, much greater casualty reductions could be expected. For example, seat belt use increased from nearly 0% in 1960 up to 75% in 2002, which by itself should reduce fatalities by about 33% (according to the National Highway Traffic Safety Administration, wearing a seat belt reduces the chances of dying in a car crash by about 45%), yet, per capita traffic deaths only declined by about 25%.

Traffic crashes continue to be one of the greatest single cause of deaths and disabilities for people in the 1-44 age range (CDC, 2003). Although the U.S. has one of the lowest traffic fatality rates *per vehicle-mile*, it has one of the highest traffic fatality rates *per capita*, as illustrated in Figure 2. From this perspective, traffic safety continues to be a major problem and mobility management can be considered an appropriate approach to reduce per-capita crash risk.

Figure 2 International Traffic Fatality Rates (OECD, 2001)



This figure compares national traffic fatality rates. The U.S. has one of the lowest rates per vehicle-kilometer and one of the highest rates per capita.

When road risk is measured using a mileage-based rate, increased vehicle mileage is not considered a risk factor and mobility management is not considered a safety strategy. From this perspective, an increase in total crashes is not a safety problem provided that there is a comparable increase in vehicle travel. Increased vehicle mileage under relatively safe conditions appears to increase safety because more low-risk miles reduce per-mile crash rates. For example, building grade-separated highways tends to reduce per-mile crash rates because they have low per-mile crash rates *and* increase vehicle mileage, although per capita crashes may increase as a result (Noland, 2003).

When evaluating safety impacts it is important to account for all costs. Some safety strategies (driving a larger and heavier vehicle) reduce risk for occupants of that vehicle, but increases risk to occupants of other vehicles. Other safety strategies (seat belts and airbags) reduce risk for occupants of the vehicle with those features, but have no direct effects on occupants of other vehicles. Other safety strategies (safer driving and reduced mileage) reduce risk for occupants of the vehicle that changes and to occupants of other vehicles.

Traffic risk can be considered to impose both *internal* costs (costs borne directly by the person imposing the risk) and *external* costs (costs borne by others in society). There are two levels of external crash costs. One is additional risk imposed on other road users by each additional vehicle in the traffic stream, due both to errors made by that additional vehicle, and errors made by other travelers which would not cause a crash if the additional vehicle were not on the road. In addition, regardless of their cause, crashes can impose economic costs not borne directly by a vehicle user, such as uncompensated productivity losses borne by families and employers of people injured or killed in a crash. Some implications of this distribution of crash costs are discussed later in this paper.

## HOW VEHICLE MILEAGE AFFECTS CRASH FREQUENCY

Crash risk can be considered the product of two factors: per-mile crash risk times annual mileage. Changing either factor affects annual crash risk. Although per-mile crash rates vary depending on various factors related to driver, vehicle and environmental conditions, these

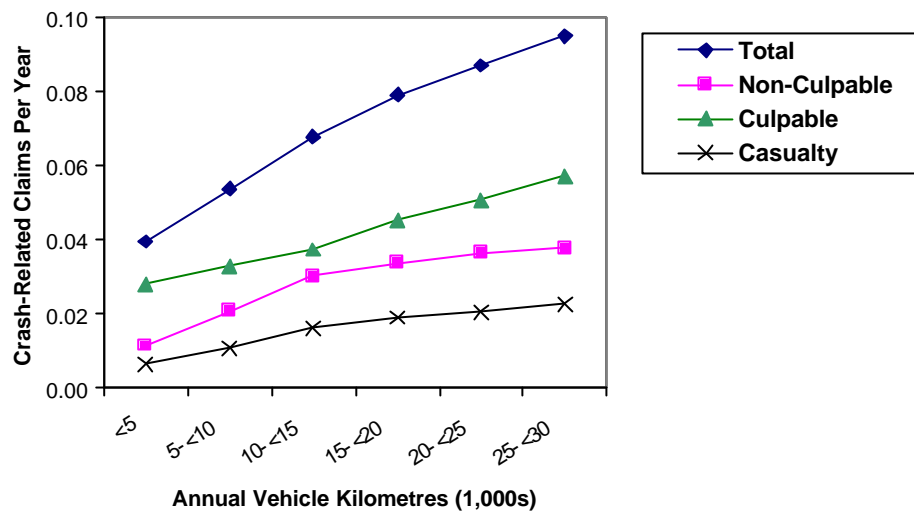
risk factors tend to change little when individual motorists change their annual vehicle mileage. A high-risk driver may average one crash every 50,000 miles, while a lower-risk driver may average one crash every 500,000 miles, but in either case reducing annual mileage reduces their annual crash risk. Even a driver who never violates a traffic rule faces risks beyond their control – errors by another driver, an animal running into the roadway, catastrophic mechanical failure, a sudden medical problem – and most drivers take minor risks that have small but real chances of contributing to a crash.

There is considerable empirical evidence from a variety of sources indicating that annual vehicle mileage has a major effect on annual crash rate (Dickerson, Peirson and Vickerman, 1998; Edlin and Karaca-Mandic, 2002; Schuffham and Langley, 2002). Insurance actuaries have long recognized annual vehicle mileage as a significant factor in annual crash and claim rates (CAS, 1996, p. 35, 242 and 250). Balkin and Ord (2001) found seasonal cycles in U.S. highway fatalities that correlate with monthly variation in vehicle mileage. Butler (1996) provides a variety of evidence that a vehicle's annual mileage is a major factor in annual crash risk and insurance claim costs. A study of young drivers found that "the consistently significant factor influencing risk of motor vehicle crash involvement was *quantity* of kilometres driven" (Bath, 1993, p. 5). Another study found traffic casualty rates tend to decline with unemployment because it reduces annual vehicle use (Mercer, 1987).

Roberts and Crombie (1995) found that after removing long term trends, there was a close relationship between the year-to-year variation in U.S. traffic volumes and child pedestrian death rates. When traffic volumes fell, reductions in child pedestrian death rate were considerably larger than those seen at any other time. They conclude that while other factors may determine long-term trends, child pedestrian death rates are very sensitive to short-term variations in traffic volume, so public policy changes which reduce traffic volumes can reduce pedestrian death rates.

Figure 3 illustrates the relationship between annual mileage and crash rates based on mileage readings collected during annual emission inspections matched with individual vehicles' insurance claims for more than 700,000 vehicle-years (Litman, 2001). The data show a strong positive relationship between annual mileage and annual claims, and similar relationships were found when these data were disaggregated by pricing factors such as driver history, type of vehicle use and territory. The results indicate that, all else being equal, annual crash and insurance claims increase with annual mileage.

Figure 3 Insurance Claim Rates by Annual Vehicle Mileage (Litman, 2001)



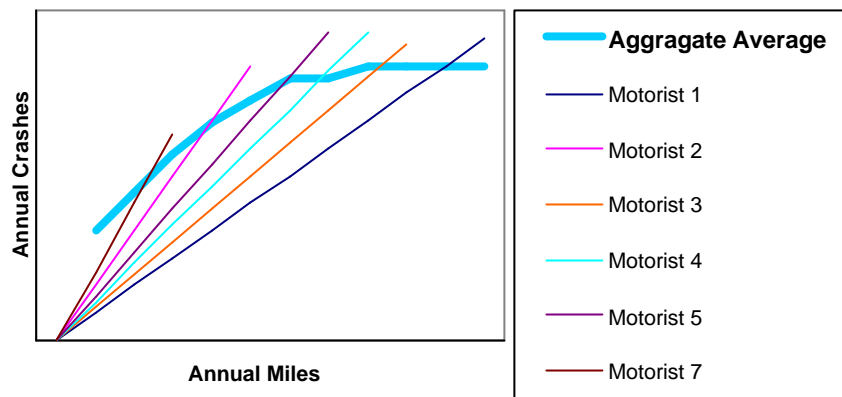
Claims per vehicle tend to increase with annual mileage. ("Culpable" refers to drivers responsible for causing a crash. "Casualty" means a crash caused a human injury or death.)

Several factors tend to partly offset this positive relationship between mileage and crashes for groups of vehicles (Janke, 1991):

- Motorists who are higher-risk per vehicle-mile due to age or disability tend to drive lower annual mileage, while high annual-mileage motorists tend to be relatively capable drivers.
- Newer, mechanically safer vehicles tend to be driven more each year than older vehicles.
- Urban drivers tend to have higher crash rates due to increased traffic density, and drive fewer annual miles, than rural drivers.
- High mileage motorists tend to do a greater share of driving on grade-separated highways that have relatively low per-mile crash and fatality rates.
- There may be other types of offsetting behaviors by which higher-mileage drivers take more precautions to limit their risk, such as purchasing safer vehicles.

These factors result in the crash/mileage curves that level off for high annual mileage groups, as indicated in Figure 3. However, these factors represent differences *between different motorists*. Most of the offsetting factors listed above do not change when an *individual driver* marginally reduces annual mileage, so the relationship between mileage and crashes is more linear for individual drivers, as illustrated in Figure 4. For example, a motorist whose annual mileage declines from 12,500 to 11,500 miles in response to improved travel options or pricing incentives is unlikely to become less skilled, take greater chances or drive an older vehicle, so a reduction in mileage is likely to cause an approximately proportional reduction in their crash rate.

Figure 4 Crashes Per Year



*Individual motorists' curves are probably straighter than the aggregate, due to offsetting factors between different motorists which result in higher per-mile crash rates by lower-annual-mileage motorists. An individual motorist that reduces mileage is unlikely to increase their per-mile crash rate.*

Some insurance industry experts argue that annual vehicle mileage has a minor effect on annual crash risk compared with demographic factors such as driver age and gender, vehicle type and geographic factors (Cardoso and Woll, 1993). However, whether mileage is more or less important than these other factors is irrelevant to mobility management: when demographic, vehicle and geographic factors are held constant (that is, for a particular motorist), annual mileage appears to have a major effect on a vehicle's annual crash rate, and mileage reductions can be expected to reduce per capita crashes.<sup>1</sup>

Since about 70% of crashes involve multiple vehicles, changes in mileage can cause proportionally greater changes in *total* crash costs (Vickrey, 1968; Edlin and Karaca-Mandic, 2002). Reducing mileage reduces both your exposure to other drivers' errors and their exposure to your errors. As a result, even perfect drivers who makes no errors increase safety by reducing mileage due to the reduced chance of being hit by another road user.

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<sup>1</sup> The insurance industry has never had reliable mileage data, since motorists tend to underestimate their annual mileage to insurance companies in order to obtain lower rates. See Patrick Butler, Twiss Butler and Laurie Williams, "Sex-Divided Mileage, Accident, and Insurance Cost Data Show that Auto Insurers Overcharge Most Women," *Journal of Insurance Regulation*, Vol. 6, No. 3&4, 1998.

Table 3 Crash Categories

A	B	C	D
Single-Vehicle	<b>Multi-Vehicle</b>	<b>Multi-Vehicle</b>	Single-Vehicle
Your Fault		Others' Fault	

*Changes in travel affect different categories of crashes in different ways. Multi-vehicle crashes are affected by both your behavior and the behavior of other motorists. These crashes involve greater costs because more vehicles and passengers are involved.*

To illustrate this concept, Table 3 divides crashes into four categories labeled A-D, depending on whether they are single- or multiple-vehicle crashes, and whether they are *Your* or *Others* fault. If you reduce your chances of causing a crash by 10% (perhaps by driving more cautiously or using a vehicle with better brakes), you reduce crash categories A and B, and your total crash risk declines by about 7%, but the 30% of crashes that you are involved in which are caused by other motorists' mistakes are not reduced. If your annual mileage declines by 10%, your chance of causing a crash declines by 10% (crash categories A and B), and your risk of being in a collision caused by other drivers' mistakes (crash category C) also declines 30%. If all other motorists reduce their mileage by 10%, but you do not, you can expect a 7% reduction in crash risk, since 70% of your crashes involve another vehicle (you are less exposed to their mistakes and they are less exposed to your mistakes), resulting from a reduction in crash category C. If all motorists reduce mileage by 10% and other factors are held constant, total crashes should decline about 17% (10% + 7%), resulting from a reduction in all crash categories, A-D.

Reductions in crash categories B and C provide greater total safety benefits than reductions in crash categories A and D, because they involve multiple vehicles and so cause greater physical damage and injury per crash. Thus, an action that reduces your chance of being involved in a multi-vehicle crash by 10% reduces total crash costs by 20% (including damages to you and to others), because multi-vehicle crash cause about twice the damage as a single-vehicle crash. Table 4 summarizes these impacts.

Table 4 Summary of Risk Impacts

	Categories of Crash Reduction
You reduce your per-mile risk.	A & <b>B</b>
You reduce your mileage.	A, <b>B &amp; C</b>
Others reduce their per-mile risk.	<b>C &amp; D</b>
Others reduce their mileage.	A, <b>B &amp; C</b>
Everybody reduces per-mile risk or mileage.	A, <b>B, C &amp; D</b>

*This table summarizes the categories of crashes reduced by various types of safety actions. Bold categories (B & C) involve multiple vehicles and so cause greater costs per crash.*

With current pricing, motorists do not face efficient pricing with respect to crash costs. There are three reasons for this. First, vehicle insurance premiums are currently fixed with regard to mileage. Second, as described above each additional vehicle added to the traffic stream increases crash risk to other road users. Third, some crash costs are uncompensated by insurance. The optimal marginal per-mile charge for vehicle crash risk is likely to be higher than what would be required for crash compensation cost recovery (Vickrey, 1968). If insurance is priced by the mile, the socially optimal premium would be somewhat higher than what would be calculated by simply prorating current premiums by mileage, since not

only does safer driving and reduce mileage reduce the claim costs borne by that insurance company, it tends to reduce insurance claim costs borne by other insurers and crash costs to society as a whole. Only if a single company has a monopoly on all vehicle insurance would it perceive the full insurance cost savings from increased safety, and even that does not account for uncompensated crash costs. For these reasons, automobile use is underpriced with regard to its marginal crash costs, resulting in increased crashes and increases in other external costs of driving such as congestion, parking and roadway facilities and environmental impacts.

Put another way, increased mileage increases traffic density (VMT per lane-mile), which increases per-mile crash risk for all road users, and thus the frequency of multi-vehicle crashes. Traffic density tends to be a major factor in per-mile crash rates, which is why crash rates and insurance costs tend to be higher in urban areas compared with rural areas. Table 5 shows how crash rates vary by road type in one jurisdiction. *Crash* rates are three times higher for urban driving, although *fatality* rates are about twice as high for rural driving.

Table 5 Iowa Crash and Fatality Rates Per 100 Million Veh.-Miles (IDOT, 1995)

	All Crash	Fatal Crash	Fatal + Injury Crash
<b>Rural</b>			
Interstate	57	0.45	18
Primary	133	1.97	42
Secondary	261	3.26	94
<i>Total</i>	<i>147</i>	<i>1.91</i>	<i>50</i>
<b>Urban</b>			
Interstate	137	0.69	54
Primary	472	1.15	181
Secondary	558	0.79	174
<i>Total</i>	<i>469</i>	<i>0.88</i>	<i>157</i>

*Crash rates tend to be higher in urban areas, but fatality rates tend to be higher in rural areas.*

Three factors could partly offset the additional traffic risk from increased mileage. First, increased mileage tends to increase traffic congestion, which, although it increases crash frequency can reduce crash severity. Second, drivers may be more cautious when traffic density increases. Third, increased mileage may justify increased roadway investments, leading to more driving on roadways with lower per-mile crash rates, such as grade-separated highways. However, empirical evidence indicates that per-mile crashes do increase with traffic density, so marginal changes in total annual vehicle mileage tend to cause a proportionately larger change in crashes (i.e., the elasticity of annual crashes with respect to annual vehicle mileage is greater than 1.0). Analyzing U.S. state-level insurance claims and traffic density data, Edlin (1998) calculated marginal crash costs per additional vehicle-mile driven. He found that the elasticity of vehicle insurance costs with respect to mileage is between 1.42 and 1.85, meaning that a 10% reduction in vehicle mileage reduces crash costs between 14% and 18%.

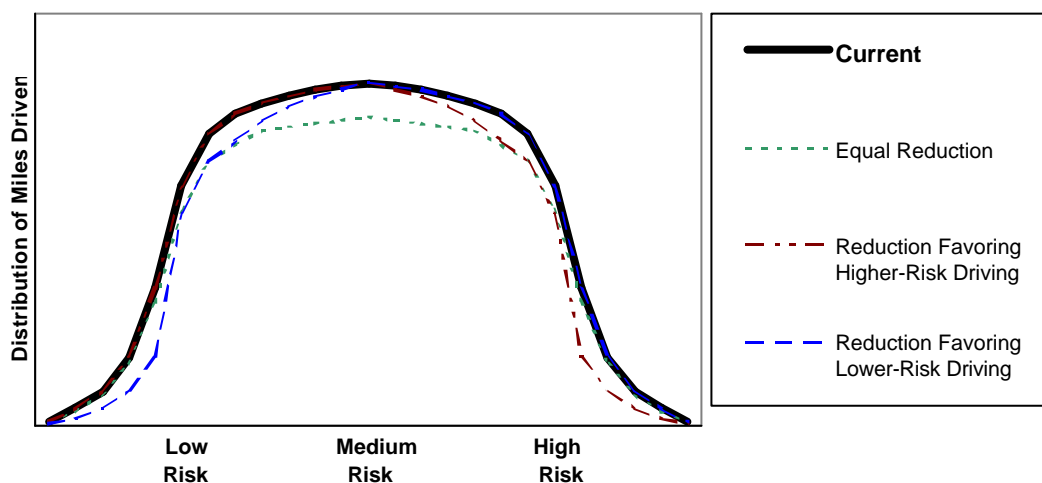
Using U.S. state-level data, Dougher and Hogarty, 1994 found that traffic injuries increase with traffic density. Using data from the London region, Dickerson, Peirson and Vickerman

(1998) found a near proportional relationship between traffic volumes and crash rates on roads with low to moderate traffic flows, but marginal crash rates rise substantially with high traffic flows, indicating that traffic accident externalities increase substantially with traffic density.

Edlin and Karaca-Mandic (2002) use state-level data to evaluate the relationships between mileage, insurance premiums and loss costs. They find that in high traffic density states, an increase in density dramatically increases insurance costs, although this does not occur in low-density states. For example, they estimate that an additional average driver added to the annual traffic flow in California increases total insurance costs by \$1,271-2,432. Their model indicates that U.S. national accident externalities total \$140 billion annually, which averages about 5¢ per vehicle mile.

The traffic safety impacts of a mobility management strategy depend on the relative crash rates of the mileage reduced. Figure 5 illustrates this concept. Risk per vehicle-mile can be assumed to follow a bell-curve, with some higher-risk and lower-risk miles. A strategy that reduces an equal portion of high- and low risk miles by 10% can be expected to reduce total crash costs by about 17% (the 10% reduction in each motorists risk to themselves, plus the 7% reduction in risk of crashing with another vehicle). Mileage reductions that favor low risk vehicle-miles will have less safety benefits, while mileage reductions that favor higher-risk vehicle-miles will provide larger safety benefits.

Figure 5 Safety Impacts Depend on the Relative Risk of Mileage Reduced



*Mobility Management safety impacts depend on the crash rates of the mileage reduced.*

Certain risk factors deserve special attention in this analysis, such as the very high crash risk associated with alcohol and drugs, and young male drivers (NHTSA, 2003). Since these behaviors can be considered special and irrational, they may be unaffected by certain mobility management strategies. Some mobility management might reduce lower-risk vehicle miles more than higher-risk vehicle miles. For example, many mobility management strategies target commute trips, and do not directly reduce vehicle trips to social events where motorists are likely to drink alcohol. Inebriated driver may not respond to pricing incentives such as parking fees, road tolls and mileage-based charges. Similarly, young males who consider cars a status symbol and enjoy the thrill of fast driving may be the least likely to reduce their mileage in response to mobility management programs and incentives. As a result, a particular mobility management program might provide relatively small safety benefits.

However, mobility management strategies can reduce these special risks in various direct and indirect ways:

- a. By reducing total vehicle miles, and therefore traffic density, mobility management reduces the risk of multiple vehicle crashes involving an irrational driver. As discussed earlier, when a motorist reduces mileage, they are less likely to be the target of another driver's mistake.
- b. Some mobility management strategies affect total vehicle ownership and mileage by higher-risk drivers. For example, a transport management program that improves travel options for students to high school or college may make automobile travel less of a necessity, and therefore reduce the number of vehicles owned and miles driven by young male drivers.
- c. Mobility management land use strategies (smart growth, new urbanism and location-efficient development) can result in more mixed land use, which reduces vehicle mileage and traffic speeds. For example, these strategies can reduce distances between homes and pubs, and increases the feasibility of walking rather than driving when returning from a pub, and so may reduce drunk mileage.
- d. Traffic management strategies, such as traffic calming and new urbanist roadway design, can reduce traffic speeds and therefore crash frequency and severity involving high-risk drivers.
- e. Improved travel options may shift public attitudes, making it easier for courts to revoke driving privileges of higher-risk drivers. In a highly automobile-dependent community motorists with multiple moving violations are often allowed to continue driving because it is considered a necessity, but this argument is weaker in more multi-modal communities.

## SAFETY IMPACTS OF SPECIFIC MOBILITY MANAGEMENT STRATEGIES

This section describes the traffic safety impacts of various mobility management strategies. There is limited research on many of these factors, and these impacts can vary depending on particular circumstances, so these findings are tentative and general, and may not apply in a particular situation. More research is needed to better determine the safety impacts of specific mobility management policies and programs.

### Vehicle Travel Reductions

Some mobility management strategies give motorists incentives to reduce annual vehicle mileage. These include road and parking pricing, commute trip reduction programs, vehicle use restrictions, marketing to promote alternative modes, and land use management strategies.

Although some automobile mileage reductions involve travel shifts to other modes, a portion of person-miles often disappear altogether. For example, people sometimes choose between closer or more distance destinations for shopping and recreational activities, or whether to make a special errand trip or consolidate several errands into one trip. Increasingly, telecommunications (telephone, fax, Internet, videoconferencing, etc.) and delivery services can substitute for physical travel. When motorists shift modes they often change their total travel. For example, when running errands people sometimes choose between walking to a nearby store or driving to a distant shopping center. Some studies indicate that given modest incentives and encouragement, many people will reduce their personal travel by 10-20%, a significant portion of which represents an absolute reduction in person-miles (TravelSmart, 2001).

As described earlier, broad mileage reductions appear to provide proportionally greater reductions in crashes. Edlin's 1998 study suggest that each 1.0% reduction in vehicle mileage reduces crash costs by 1.4-1.8%, although these impacts vary depending on the type of mileage reduced. Reductions in relatively low risk driving, such as commute trips, probably provides somewhat smaller crash reductions.

### Pay-As-You-Drive Vehicle Insurance

Pay-As-You-Drive pricing converts vehicle insurance premiums from a fixed cost into a variable cost, so motorists save when they reduce their annual mileage (Litman, 2001). Existing vehicle -year premiums are prorated by mileage, so insurance is priced by the vehicle-mile rather than the vehicle-year. This price structure gives motorists an incentive to reduce their driving proportional to their risk ratings. For example, a low-risk motorist who currently pays \$300 annually for insurance would pay about 2.5¢ per mile, and so is predicted to reduce their mileage an average of 5%, while a higher-risk motorist who currently pays \$1,800 for insurance would pay 15¢ per mile, and so might reduce their annual mileage by 20%, since they save more with each mile reduced. This represents more efficient pricing of crash risk than current fixed-rate premiums.<sup>2</sup> This should result in a greater reduction in higher-risk miles, providing extra safety benefits, although actual safety impact depend on the price structure used and the relative price sensitivity of higher- and lower-risk drivers.

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<sup>2</sup> Vickrey (1968) points out that an additional fee may often be required for marginal-cost pricing of crash risk to account for the external risk imposed by each additional vehicle in the traffic stream, and for currently uncompensated crash costs.

## Mode Shifting

Many mobility management strategies cause travelers to shift from driving to another mode, either by making alternative modes more attractive or by increasing the cost of automobile use. This can have a variety of safety impacts. Table 6 summarizes an estimate of fatality rates of different transport modes. This only reflects the internal risk to individual travelers, but does not account for changes in risk to other road users. The safety impacts of shifts to specific modes are discussed below.

Table 6 Fatalities per 100 Million Passengers in Britain (RSPC, 1997)

	Per Trip	Per Hour	Per Km
Motorbike	100	300	9.7
Air	55	15	0.03
Water	25	12	0.6
Pedalcycle	12	60	4.3
Foot	5.1	20	5.3
Car	4.5	15	0.4
Van	2.7	6.6	0.2
Rail	2.7	4.8	0.1
Bus	0.3	0.1	0.04

*This table compares crash rates of common travel modes. Faster modes tend to have low crash fatality rates per unit of travel, but not so low when measured per trip or hour of travel.*

### Transit

Transit vehicle passengers have about one-tenth the crash fatality rates of automobile occupants, and shifts to transit reduce total vehicle traffic (a bus or trolley can substitute for up to 50 automobiles, and transit users often travel less total miles than motorists). In the U.S., urban transit has a relatively high total fatality rate (including both occupants and other road users) per passenger-mile, due to low load factors (passengers per vehicle-mile), but mobility management strategies that increase transit load factors (more ridership without a comparable increase in vehicle-miles) have small marginal crash risk, and so reduce crash rates. For example, an extra bus passenger adds *internal* risk, but does not increase the external risk a bus imposes on other road users.

Transit can be a catalyst for more accessible land use patterns that reduce per capita automobile travel and therefore crash risk. Per capita traffic fatalities tend to be lower in transit-oriented urban areas than in automobile-oriented cities (Neff, 1996; Newman and Kenworthy, 1999).

### Ridesharing

*Ridesharing* refers to carpooling and vanpooling. Ridesharing reduces overall crash risk by reducing total vehicle mileage. Two people who carpool rather than drive alone bear about the same level of internal risk, but reduce risk to others by using one vehicle rather than two. Ridesharing may result in somewhat safer driving, for example, because drivers may be more cautious when they have passengers, carpools may rely on their more skilled drivers or safer vehicles, and because vanpool operators are sometimes required to take special safety tests. However, some HOV lanes have relatively high crash rates due to awkward merging

conditions, and loaded vans may have a relatively high rollover rate which may increase crash severity under some conditions (NHTSA, 2001).

#### *Nonmotorized Transport*

Walking and cycling tend to have relatively high per-mile casualty rates, as indicated in table 4, suggesting that individuals increase their risk of crash injuries and death when they shift from automobile to nonmotorized modes. However, the effects of such modes shifts on *total* risk may be partly offset by the following factors:

- a. Nonmotorized travel imposes minimal risk to other road users.
- b. Nonmotorized trips tend to be shorter than motorized trips, so total per capita mileage declines. A local walking trip often substitutes for a longer automobile trip.
- c. High crash and casualty rates for pedestrians and cyclists result, in part, because people with particular risk factors tend to use these modes, including children, people with disabilities and elderly people. A skilled and responsible adult who shifts from driving to nonmotorized travel is likely to experience less additional risk than these average values suggest.
- d. Nonmotorized travel provides health benefits that can offset crash risk.
- e. Some programs include education and facility improvements that reduce per-mile bicycle crash rates.

Empirical evidence indicates that shifts from driving to nonmotorized modes can reduce total per capita crash risk. Jacobsen (forthcoming, 2003) found that per capita collisions between nonmotorized travelers (pedestrians or cyclists) and motor vehicles decline in areas with higher rates of nonmotorized travel, suggesting that drivers become more cautious when they see more walkers and cyclists. The author calculates that the number of motorists colliding with pedestrians and cyclists increases at roughly 0.4 power of the number of people walking or cycling (e.g., doubling NMT travel in a community will increase pedestrian/cycling injuries by 32%), and the probability that a motorist will strike a nonmotorized traveler declines with the roughly -0.6 power of the number of people walking and cycling in a community (e.g., as a pedestrian, my risk of being hit by a motor vehicle declines 34% if walking and cycling double in my community).

Urban regions with high walking and cycling mode splits tend to have lower per capita traffic fatalities than more automobile-dependent communities. For example, walking and cycling travel rates are high in the Netherlands, yet the per capita traffic death rate is much lower than in automobile dependent countries (Pucher and Dijkstra, 2000). Pedestrian fatalities per billion km walked are less than a tenth as high, and bicyclist fatalities are only a quarter as high, as in the United States.

#### *Mobility Substitutes*

Mobility substitutes include telework and delivery services. The resulting mileage reductions tend to reduce crashes, although there may be rebound effects, such as the tendency of telecommuters to make special trips for errands that they would otherwise perform while commuting, and to move farther from their worksite to less accessible, exurban locations which offset a portion of mileage reductions and associated safety benefits. For example, an employee who telecommutes three days a week would reduce commute mileage by 60%, but may drive additional miles for errands, resulting in a 40% net reduction in vehicle mileage and more modest safety benefits.

### **Travel Time and Route Shifts**

Strategies that shift vehicle travel from peak to off-peak periods, or from congested highways to alternative routes, have mixed safety impacts. Crash rates per mile are lowest on moderately congested roads, and increase at lower and higher congestion levels, but fatalities decline at high levels of congestion, indicating a trade-off between congestion reduction benefits and crash fatalities (Zhou and Sisiopiku, 1997; Shefer and Rietvald, 1997). Shifting vehicle trips to less congested roadway conditions can reduce crashes, but the crashes that occur tend to be more severe due to higher travel speeds. As a result, the safety impacts of mobility management strategies that shift travel times and routes can vary, depending on specific circumstances, and are difficult to predict.

### **Traffic Speed Reductions**

There has been considerable research concerning the effects of traffic speed and speed control strategies have on road safety. This research suggests that on highways, speed variance (the range between the highest and lowest speed vehicles) tends to increase crash rates per vehicle-mile, and that high traffic speeds tend to increase crash severity (Stuster and Coffman, 1998). On urban surface streets, even modest speed reductions can prevent many collisions and reduce crash severity, and are particularly effective at reducing injuries to pedestrians and cyclists (Leaf and Preusser, 1998).

Traffic calming (roadway design strategies to reduce traffic speeds on a particular roadway) and increased traffic law enforcement tends to increase safety. A meta-analysis of 33 studies by Elvik (2001a) concluded that area-wide traffic calming programs reduce injury accidents by about 15%, with the largest reduction on residential streets (25%), and somewhat smaller reductions on main roads (10%).

### **Land Use Management**

Land use patterns can have various traffic safety and health impacts ("Land Use Impacts On Transportation," VTPI, 2002). Higher density, clustered development patterns tend to increase traffic density, which tends to increase crash rates per vehicle-mile within the area. However increased density also tends to reduce per capita vehicle mileage (particularly if increased density is implemented as part of an overall smart growth program to improve accessibility and encourage use of alternative modes) and tends to reduce crash severity (due to lower traffic speeds). As a result, per capita traffic fatalities tend to decline in higher density urban areas, and increase in more automobile dependent with dispersed land use patterns (Newman and Kenworthy, 1999).

One study of the Puget Sound region found that per capita traffic casualties are about four times higher for residents in low-density suburbs than for residents in higher-density urban neighborhoods (Durning, 1996). This occurs because on average suburban residents drive three times as much and twice as fast as urban dwellers. All told, city residents are safer, taking into account risks that increase with urban living, such as pedestrian traffic fatalities and homicides (Lucy, 2002). More multi-modal communities may also increase exercise and physical fitness, providing public health benefits (Frank and Engelke, 2000).

This suggests that mobility management strategies which create more clustered, accessible land use and more balanced transport systems can increase traffic safety and health, although it is difficult to quantify these impacts with existing knowledge.

### **Vehicle Use Restrictions and Car-Free Planning**

Some communities have implemented various programs that restrict vehicle use, for example, No-Drive Days during which a certain portion of vehicles are prohibited from driving, prohibiting driving on certain streets at certain times, and “car free” housing developments, which limits private automobile ownership by residents. Although in theory these reduce vehicle mileage and therefore crash risk, much of the automobile travel is shifted to other times and locations. For example, motorists may simply defer automobile errand trips from No-Drive Days to other days, and motorists may simply detour around car-free districts, resulting in the same or greater mileage and crash risk. Only if restrictions are implemented as part of an overall program to improve travel options and create more accessible land use patterns are they likely to reduce total per-capita crash risk.

### **Safety Impacts Summary**

Table 7 summarizes the road safety and public health impacts of various travel changes resulting from mobility management. Some of these impacts overlap. For example, a vehicle travel reduction strategy often involves some travel shifting from driving to transit or nonmotorized modes.

Table 7 Mobility Management Safety and Health Impact Summary

<b>Travel Change</b>	<b>MM Strategies</b>	<b>Expected Safety Impacts</b>
Vehicle Mileage Reductions	Pricing reforms, mobility management programs, various mobility management strategies.	Increases safety by reducing the risk of causing a crash and being hit due to other drivers' errors. Reductions in vehicle-miles are likely to cause proportional or greater reductions in crashes, although exact impacts depend on circumstances.
PAYD Insurance	PAYD Insurance and registration fees.	Potentially large safety benefit. Reduces total traffic and gives high-risk motorists an extra incentive to reduce mileage.
Shifts to Transit	Transit Improvements, HOV Priority, Park & Ride	Increases safety due to reduced risk to transit passengers and reduced vehicle traffic. Can increase safety and health if transit travel leads to reductions in total person-miles and increases walking.
Shifts to Ridesharing	Ridesharing, HOV Priority	Modest safety benefits. Increases safety due to reduced vehicle traffic.
Shifts to Nonmotorized Modes	Walking and Cycling Improvements, Traffic Calming	Mixed. Increases crash risk to participants, but reduces risk to other road users, reduces total person-miles, and improves fitness and health. Some programs include special activities to increase walking and cycling safety.
Mobility Substitutes	Telework, Delivery Services	Increases safety by reducing vehicle mileage, but rebound effects may offset a portion of benefits.
Time & Route Shifts	Flextime, Congestion Pricing	Mixed. Reducing congestion tends to reduce crashes but increases the severity of crashes that do occur.
Traffic Speed Reductions	Traffic Calming, Speed Enforcement	Increases safety by reducing crash frequency and severity, and reducing total vehicle mileage. Can increase nonmotorized travel.
Land Use & Transport System Changes	Various land use management and planning reforms	Increases safety by reducing per capita vehicle travel. May increase traffic congestion, increasing crash frequency but reducing crash severity. Tends to increase walking and cycling, providing fitness benefits.
Reduced driving at particular times and locations	Vehicle use restrictions, carfree planning	May shift vehicle travel to other times and routes, providing no reduction in crash risk, unless implemented as part of a more comprehensive mobility management program.

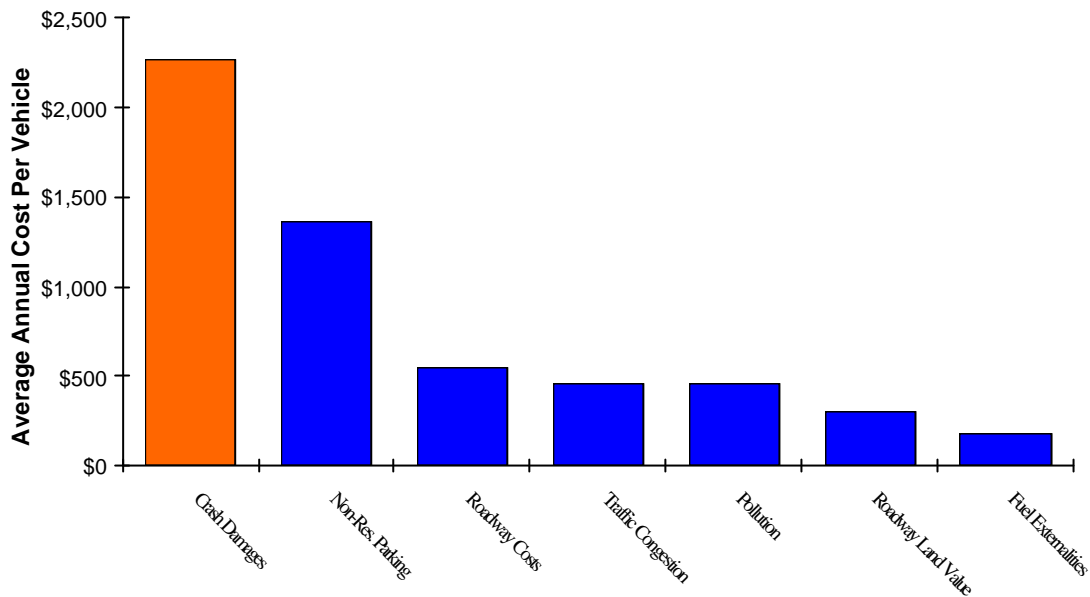
## MOBILITY MANAGEMENT EVALUATION

As described earlier, annual crash risk can be considered the product of per-mile risk times annual mileage. Current traffic safety analysis tends to focus on per-mile risk, with little consideration of mileage as a risk factor or the potential safety benefits of mileage reduction strategies. How this affects traffic safety evaluation is discussed below.

Mobility management strategies are usually evaluated based on cost effectiveness analysis for achieving one or two objectives. Transportation agencies evaluate mobility management based on cost-effectiveness for reducing road congestion, and environmental agency evaluate mobility management in terms of reducing pollution emissions. Traffic safety benefits are generally overlooked.

It can be useful to *monetize* (measure in monetary value) costs for comparison. A number of studies have attempted to calculate the full cost of traffic crashes, including both market and non-market costs, and therefore the full benefits to society of increased traffic safety (Miller, 1991; Wang, Knipling and Blincoe, 1999). Crash costs are generally considered to be one of the largest categories of costs associated with motor vehicle use (TTI, 2001; Delucchi, 2000; Litman, 2003). Total annual U.S. motor vehicle crash costs are estimated to exceed \$500 billion, about five times greater than traffic congestion or vehicle air pollution costs, as illustrated in Figure 6.

Figure 6 Costs of Motor Vehicle Use in the U.S. (Litman, 2003)



*This figure illustrates the estimated magnitude of various transportation costs. Crash damages are one of the largest costs, far greater than traffic congestion or pollution costs.*

The relative magnitude of these costs has important implications. It suggests that a congestion or emission reduction strategy may not be worthwhile overall if it causes even a modest increase in crash costs. For example, if roadway capacity expansion reduces congestion costs by 10% but increases crash costs by 2% due to induced vehicle travel or higher traffic speeds, it may not be a good investment. On the other hand, a congestion reduction strategy can provide much greater total benefits if it causes even small reductions in crashes. A mobility management strategy that reduces congestion costs by 5%, provides twice as much total benefit to society if it also reduces crash costs by 1%.

For example, a study sponsored by Transport Canada (TC, 1999) evaluated various ways to reduce climate change emissions, including vehicle design changes that reduce emissions per vehicle-mile, and mobility management strategies that reduce total vehicle mileage. The evaluation framework considered the impacts that various strategies might have on per-mile crash rates, but did not consider the traffic safety impacts of any changes in mileage (increased crashes from strategies that increase mileage, and crash reductions from strategies that reduce mileage). As a result, the Transport Canada evaluation undervalues mobility management strategies (Litman, 2000).

In recent years there has been considerable debate concerning the effects that generated and induced mileage have on congestion reduction efforts and vehicle emissions, but this debate has given relatively little consideration to safety impacts. Elvik (2001a) points out that, although highway capacity expansion is often justified based on projected crash reductions, true increases in road safety will only occur if the roadway improvement avoids increasing traffic volumes and speeds. Research by Noland (2003) suggests that "improving" highways increases crashes overall, apparently due to increased vehicle traffic mileage and speed.

In the past, North American traffic safety experts tended to favor technological solutions (e.g., wider roads, crashworthy vehicles, airbags) over behavioral solutions (seat belt use, slower speeds, reduced vehicle mileage), on the grounds that it is difficult to change

motorist behavior (Gladwell, 2001). However, it turns out that North American consumers *do* value safety. Motorists respond positively to campaigns to encourage seat belt use, helmets use and sober driving, and many are willing to pay a premium for vehicle safety features. Much greater road safety gains have resulted from behavior changes such as increased seatbelt than from passive crash protection technologies. Similarly, there is evidence that at the margin, many consumers would prefer to drive somewhat less than they do now, if given suitable incentives and convenient, safe and affordable alternatives.

Similarly, many transportation professionals hesitate to promote mobility management because they believe that travel reductions are difficult to accomplish, or will reduce the consumer and economic benefits associated with driving. However, just as safety experts discovered that many motorists prefer safety, there is evidence that at the margin (that is, compared with current travel patterns), many motorists would prefer to drive somewhat less and rely more on travel alternatives, provided that they have suitable options and incentives. This consumer preference for reduced automobile dependency is indicated by the success of many mobility management programs that rely mainly or entirely on positive incentives such as improved travel options, marketing and education programs, and parking cash out. People who continue to drive their current mileage are no worse off, in many cases 10-30% of automobile trips are eliminated. This indicates that those consumers prefer alternatives to driving.

Many mobility management strategies can be considered market reforms that correct existing market distortions that reduce consumer options and underprice driving. By increasing market efficiency such strategies can reduce vehicle travel and make consumers and the economy better off overall.

Current transport planning practices that give little or no consideration to safety impacts of changes in vehicle mileage tend to overvalue roadway and vehicle improvements that induce vehicle traffic, and undervalue mobility management programs that reduce vehicle traffic.

## HOW MUCH SAFETY CAN MOBILITY MANAGEMENT PROVIDE?

It is interesting to speculate how much safety mobility management can provide in a cost effective way, and how this compares with other traffic safety strategies. Below are some examples.

- a. Pay-As-You-Drive vehicle insurance and registration fees convert two major fixed costs into variable costs with respect to vehicle travel. Together they are predicted to reduce private automobile travel by at least 10%, and because they give higher-risk motorists the greatest incentive to reduce mileage, they provide an elasticity of crash reductions with respect to mileage reductions of at least 1.2, so if fully implemented they would reduce crashes by 12% or more.
- b. Parking Pricing (charging motorists directly for the parking they use) and Parking Cash Out (allowing people who are offered subsidized parking to choose the cash equivalent if they use alternative modes) tends to reduce automobile trips by about 20% where applied. Assuming an elasticity of 1.0, and that pricing can be applied to half of all parking activity, it would reduce crashes approximately 10%.
- c. Personalized marketing programs have been able to reduce local vehicle trips by 7-14% with moderate costs (TravelSmart, 2001). Assuming a 10% average reduction and an elasticity of 1.0, such programs would reduce crashes approximately 5-10%.
- d. The city of London's congestion pricing program reduced urban vehicle trips by 20%. This is likely to reduce crashes within that area by about 20%.
- e. Residents of new urbanist communities tend to drive 15-25% fewer miles than otherwise demographically comparable households located in more conventional, automobile oriented communities ("Land Use Impacts on Transportation," VTPI, 2003).

A mobility management program that incorporates a variety of cost-effective strategies (e.g., road pricing, parking pricing, improved travel options, marketing, and smart growth land use policies) can reduce per capita vehicle travel in a community by 20-30%, and even more if state and federal policies are also reformed.

Contrast these predicted safety gains with the crash reductions likely to be achieved by more well-known traffic safety strategies. For example, the National Highway Traffic Safety Administration estimates that each 1 percentage point increase in seatbelt use saves approximately 250 lives, so increasing seatbelt use from the current 75% to 90% would reduce crash fatalities by about 10% (NHTSA, 2002). About 35% of fatality crashes involve a drunk driver, so halving drunk driving could reduce traffic fatalities by about 18%. Airbags are estimated to reduce crash fatality risk by 7-10%, so doubling the portion of vehicles with airbags is likely to reduce fatalities by 3-5%.

This suggests that cost-effective mobility management programs can reduce an equal or greater number of traffic fatalities than many well-known safety strategies, while providing additional benefits from congestion reductions, road and parking facility cost savings, consumer benefits, environmental quality improvements, and exercise-related health benefits.

## CONCLUSIONS

Past traffic safety programs have reduced per-mile crash rates. When evaluated from this perspective, crash risk is declining and current safety programs can be considered effective. However, increased vehicle mileage has offset a significant portion of these gains. Per capita crash costs have declined relatively little despite significant improvements in roadway and vehicle safety, seat belt and helmet use, emergency responses and medical treatment. From this perspective, traffic crashes continue to be a major problem and new approaches are needed to improve safety.

Mobility management includes a variety of strategies that change travel behavior to achieve transport planning objectives. Mobility management programs can provide a variety of benefits including traffic congestion reductions, road and parking facility cost savings, consumer cost savings, energy conservation, pollution reduction, increased safety and public health, and support for various land use and equity objectives.

The safety benefits of mobility management vary depending on the type of travel changes that occur. These impacts are difficult to predict given current knowledge. Available information suggests the following safety impacts:

- a. Mobility management strategies that reduce overall vehicle travel can provide large safety benefits. Broad reductions in vehicle travel probably provide proportional or greater reductions in crashes.
- b. Pay-As-You-Drive Vehicle Insurance reduces total vehicle mileage and gives higher-risk drivers an extra incentive to reduce their mileage, and so can be particularly effective at reducing road risk.
- c. Strategies that shift travel from driving to transit or ridesharing tend to provide medium to large safety benefits, depending on the specific situation. Strategies that increase ridership using existing vehicle capacity provide the greatest safety benefits.
- d. Strategies that shift automobile travel to nonmotorized modes may increase per-mile risk for the people who change mode, but this can be offset by reduced risk to other road users, reduced trip length, and health benefits from increased exercise.
- e. Strategies that reduce traffic speeds can reduce per-mile crash frequency and severity, particularly in urban areas.
- f. Strategies that reduce traffic congestion tend to reduce crash frequency but increase severity, because crashes occur at higher speeds. As a result, mobility management strategies that shift automobile travel time, route or destination but do not reduce total vehicle travel probably do little to increase road safety overall.
- g. Strategies that create more accessible land use patterns and more balanced transportation systems may increase crash rates per lane-mile (due to increased traffic density and congestion) but tend to reduce per capita fatalities and increased aerobic health.
- h. Strategies that limit automobile traffic in an area may reduce crashes if they reduce total vehicle mileage, but may do little to improve safety if they simply shift traffic to other times or routes.

These conclusions are tentative, and variable depending on specific conditions. For example, mode shifts from automobile to cycling may reduce crash costs if it involves responsible

adults in a community with good cycling conditions, but may increase crash costs if it increases cycling by less responsible people or if cycling conditions are hazardous.

Crashes are one of the largest categories of costs associated with motor vehicle use, several times greater than congestion or pollution costs. This indicates that road safety impacts should be a priority when evaluating transport policies. A program that reduces traffic congestion or emissions by 10% but increases per capita crash costs by 3% is probably not worthwhile overall. On the other hand, a traffic congestion or pollution reduction strategy is far more valuable to society if it also reduces crash costs.

Transportation professionals generally consider mobility management a way to reduce traffic congestion and vehicle emissions. Traffic safety impacts of changes in mileage are often overlooked. As a result conventional planning overvalues roadway and vehicle changes that induce mileage, and undervalue mobility management programs that increase safety by reducing mileage. Yet, increased safety appears to be one of the largest potential benefits of mobility management, and mobility management programs may be among the most cost effective ways to improve traffic safety.

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