Safe Travels
Evaluating Mobility Management Traffic Safety Impacts
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Abstract

This paper investigates the traffic safety impacts of *mobility management*, which consists of various strategies that increase transportation system efficiency by changing travel behavior. Safety impacts depend on types of travel changes that occur. Because most crashes involve multiple vehicles, reducing vehicle mileage reduces risk both to motorists who drive less and to other road users. Mileage reductions tend to provide a proportionately larger reduction in total crash costs. Empirical evidence indicates that each percentage reduction in total vehicle mileage in an area reduces total crash costs by 1.0% to 1.4%. The safety impacts of mode shifting depends on the relative risks of each mode. Shifting vehicle travel from congested roads to less-congested conditions tends to reduce crashes but increases crash severity due to higher vehicle speeds. Strategies that reduce traffic speeds provide significant safety benefits. Conventional traffic risk analysis often understates the full safety benefits of mobility management. 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.

Introduction

Most people would probably agree that traffic crashes are one of the greatest transportation problems, costing tens of thousands of lives and hundreds of millions of dollars annually in North America.[1] For people aged 1 to 40, traffic crashes are the single greatest cause of fatalities and disabilities, and therefore a major cause of lost years of productive life (Murray, 1996). Many consumers consider safety an important consideration when choosing vehicles, and willingly pay a significant premium in purchase and operating costs for vehicles that offer extra safety features and crash protection. Safety is also given paramount consideration in the design and operation of roads and transportation services. Yet, safety is not usually a consideration when planners make decisions related to how much vehicle travel will occur, nor is it usually a justification for traffic reduction programs. This may be an oversight. In fact, safety may be one of the greatest benefits of mobility management.

Mobility management (also called *transportation demand management* or *TDM*) includes various strategies that increase transportation system efficiency by changing travel 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.

Table 1 **Mobility Management Strategies** (VTPI, 2004)

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

This table lists various mobility management strategies.

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[1] To put traffic crash risk in perspective, the September 2001 terrorist attack deaths equal about one month's normal traffic fatalities in North America. Each fatality represents about 15 major injuries, 70 minor injuries and 150 property damage only crashes ("Safety and Health Impacts," Litman, 2004a).

This paper explores the effects mobility management can have on traffic safety and the degree to which these impacts are considered in conventional transportation planning. It is both a conceptual paper and an attempt to synthesize relevant empirical studies. It builds on the work of other research concerning the relationships between mobility and crash risk (Vickrey, 1968, Wilde, 1984; Haight, 1994; Dickerson, Peirson and Vickerman, 1998; Andrey, 2000; Edlin and Karaca-Mandic, 2002).

This issue can be considered both simple and complex. It is simple because vehicle mileage undoubtedly affects crash frequency. All else being equal, reduced mileage should reduce crashes. However, it is complex because mobility management strategies have various travel impacts (Table 2), which have various impacts on crash rates and severity. 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. Some travel changes reduce risk for one group but may increase it for others. It is therefore important to understand how individual mobility management strategies affect travel and how such changes affect crash risks.

Table 2   **Examples of TDM Travel Impacts**

| TDM Strategies	Travel Changes
Commute trip reduction	Reduces automobile commute trips, shifts to alternative modes.
Flextime	Reduces peak-period vehicle travel on a particular roadway by shifting travel time.
Compressed workweek	Reduces commute trips.
Congestion pricing	Reduces peak-period vehicle travel on a particular roadway by shifting travel route, time, destination and mode.
Distance-based charges	Reduces overall vehicle travel.
Transit improvements	Shifts mode, increases transit use.
Rideshare promotion	Increases vehicle occupancy, reduces vehicle trips.
Pedestrian and bicycle improvements	Shifts mode, increases walking and cycling.
Telework	Reduced vehicle travel.
Carsharing	Reduces vehicle ownership and trips.
Smart Growth, New Urbanism	Creates more accessible land use, reduces trip distances, shifts modes (to walking, cycling and public transit) and reduces travel speeds. Increases traffic density.
Traffic Calming	Reduces traffic speeds, improves pedestrian conditions.

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

Evaluating Crash Risk

Safety evaluation is affected by how crash risk is measured. Traffic safety studies measure *crashes* (also called *incidents*, *accidents* or *collisions*), *injuries* and *fatalities* (injuries and fatalities together are called *casualties*). Crash statistics may reflect either *reported* crashes or estimates of *total crashes* (by multiplying reported crashes by some estimate of the portion of crashes that are unreported). Crash data may include just "users" (the people using a particular vehicle or mode), or it can also include "others" (other road users or bystanders). Different types of data can give very different conclusions about the nature of traffic risk and how traffic safety can be improved.

Figure 1 illustrates traffic fatality rates using two different denominators. 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.

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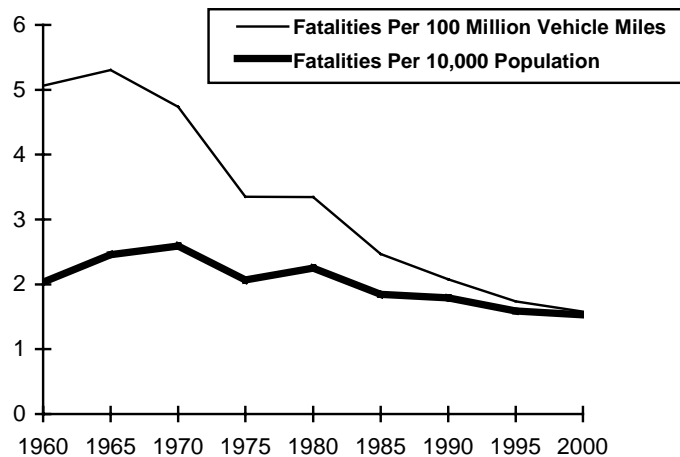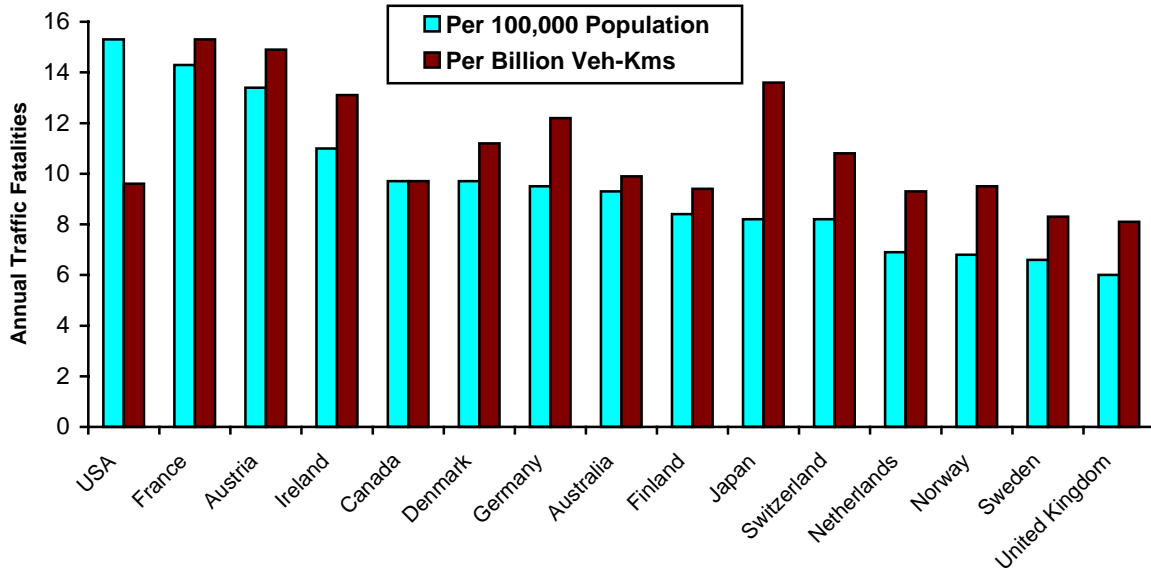

This figure illustrates traffic fatality trends over four decades. When crashes are measured per vehicle mile, they decline significantly, but when measured per capita they show relatively little decline due to increased per capita vehicle mileage over this time period.

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 was little improvement during this period despite significant road and vehicle design improvements, increased use of safety devices, reduced drunk driving, and better emergency response and medical care. Taking these factors into account, much greater casualty reductions could be expected. For example, seat belt use increased from nearly 0% in 1960 to 75% in 2002, which by itself should reduce per capita traffic 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 aged 1-44 years (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 risk continues to be a major problem.

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 yet 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, grade-separated highways have low per-mile crash rates and stimulate increased vehicle mileage. As a result, they tend to reduce per-mile crash rates but increase per capita crash rates (Noland, 2003).

When evaluating safety impacts, it is important to account for both *internal* costs (costs borne directly by the person imposing the risk) and *external* costs (costs borne by others in society). For example, increased vehicle weight reduces occupants' risk but increases risk to other road users. Some safety strategies (seat belts and airbags) reduce risk for that vehicle's occupants, but have no direct benefits for other road users. Other safety strategies (safer driving and reduced mileage) reduce crash frequency and therefore reduce both internal and external risks.

How Vehicle Mileage Affects Crash Frequency

To evaluate mobility management safety impacts it is important to understand how changes in total vehicle mileage affect crashes in an area. Crash risk can be considered the product of two factors: per-mile crash risk times annual mileage. Changing either factor affects annual crash frequency. 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 drivers who never violate traffic rules face 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 with small but real chances of contributing to a crash.

Crash casualty rates tend to vary significantly from one geographic area to another due to differences in road and vehicle quality, driver and other road user behavior, emergency response, and medical treatment. Many less developed countries have high per capita traffic fatality rates, despite low levels of motorization, and these high crash rates often decline as per capita vehicle travel increases. For example, as a group, high-income countries are estimated to average 11.8 annual traffic fatalities per 100,000 population, compared with 19.2 in the Middle East/North Africa, and 26.1 in Latin America/Caribbean, despite much lower rates of per capita vehicle travel (WHO, 2004, Table 2.5).[2] This implies that increased mileage *reduces* traffic risk.

Despite large variations in crash casualty rates between areas at different stages of development, there is considerable evidence from numerous sources indicating that for a particular geographic area or homogeneous group, annual per capita vehicle mileage has a major effect on per capita crash rates (Vickrey, 1968; Roberts and Crombie, 1995; Dickerson, Peirson and Vickerman, 1998; Edlin, 1998; Balkin and Ord, 2001; Edlin and Karaca-Mandic, 2002; Schuffham and Langley, 2002; Clark and Cushing, 2004). This suggests that for a particular area, group or individual, reducing mileage reduces crashes.

Balkin and Ord (2001) found seasonal cycles in U.S. highway fatalities, with annual peaks during holiday seasons when VMT increases. During various recessions, reductions in annual mileage due to reduced employment and incomes generally reduce per capita crash rates. For example, a recession in 1981-82 caused a 10% reduction in vehicle travel and a 12% reduction in insurance claims in British Columbia (ICBC data). Female drivers' lower crash rates are approximately equal to their lower average mileage (Butler, 1996). As figure 3 indicates, when U.S. annual mileage increased relative to the long-term trend, crashes also tend to increase, and periods with reduced mileage tend to have reduced crashes.

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[2] Unfortunately, mileage and traffic fatality data from middle- and lower-income countries tends to be limited and unreliable, so it is difficult to accurately compare crash rates.
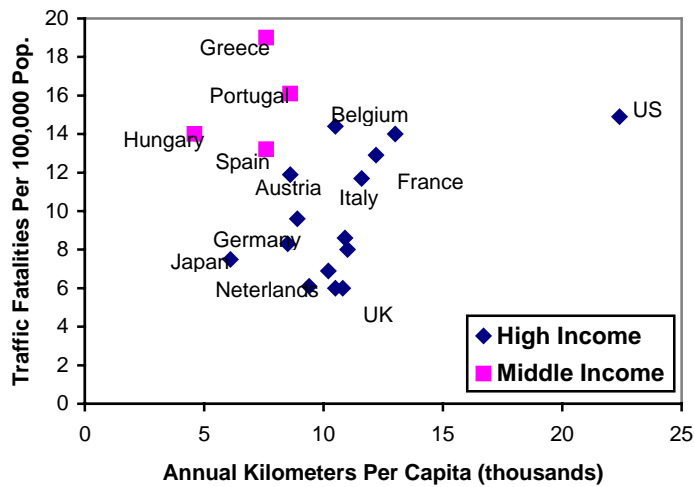
Figure 3 **Vehicle Mileage and Crash Fatality Variation**
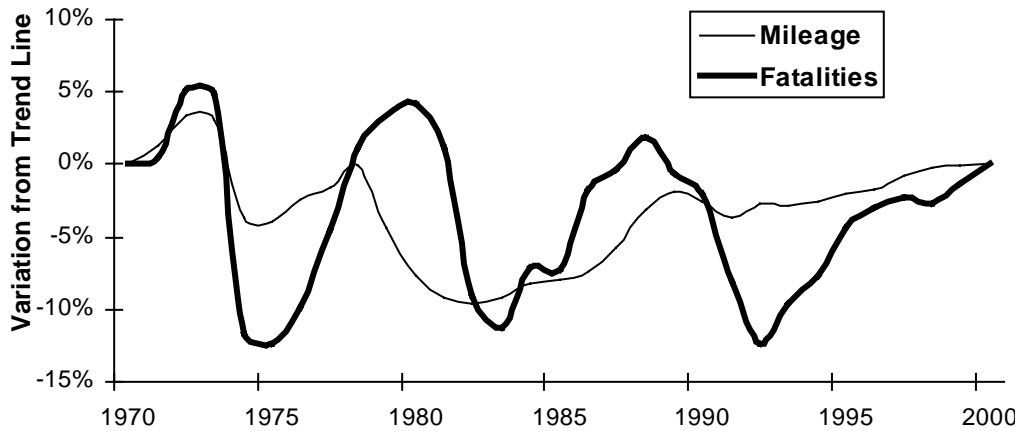
This figure indicates a correlation between annual mileage and crash fatalities. When vehicle travel declined in 1973-76, 1978-83 and 1990, fatalities also declined. When vehicle travel increased after 1976-78 and 1986-90, fatalities also increased.

Figures 4 and 5 show international data on the relationships between average annual per capita vehicle mileage and traffic fatality rates. Figure 4 indicates that middle income European countries tend to have relatively high traffic fatality rates despite relatively low annual vehicle mileage, but among higher income countries as a group, traffic fatality rates tend to increase with mileage. Figure 5 shows a similar relationship for various international cities: as vehicle mileage increases, so do per capita traffic deaths.

***Figure 4*** **International Vehicle Mileage and Crash Rates, 2001** (DfT, 2004)

This figure shows annual per capita vehicle mileage and traffic fatality rates for several High and Middle Income countries. Middle Income countries tend to have higher crash rates than High Income countries, but within each group, crash rates tend to increase with mileage.

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Figure 5   **Per Capita Vehicle Travel and Fatalities** (Kenworthy and Laube, 2000)
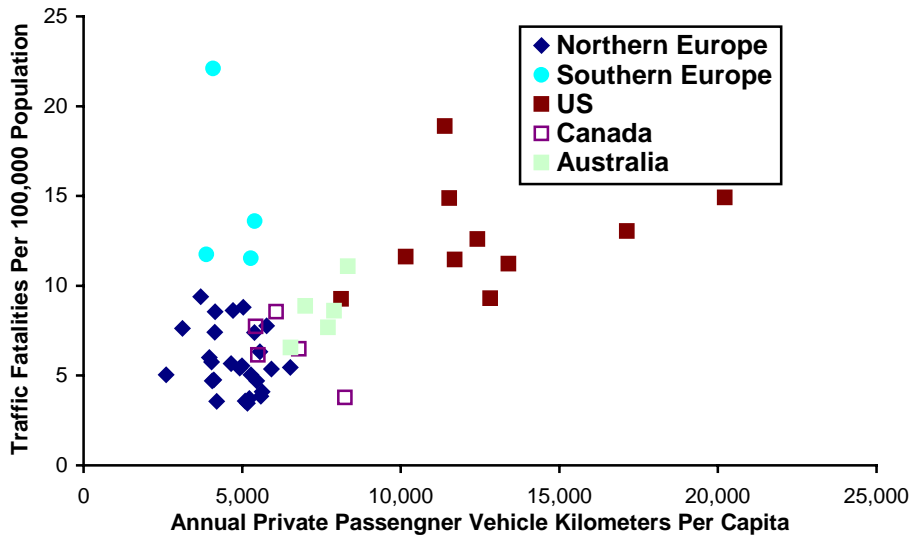
As per capita vehicle travel increases in a city, so do traffic fatalities.

Figure 6   **U.S. Traffic Fatality and Mileage Rates** (Clark and Cushing, 2004)
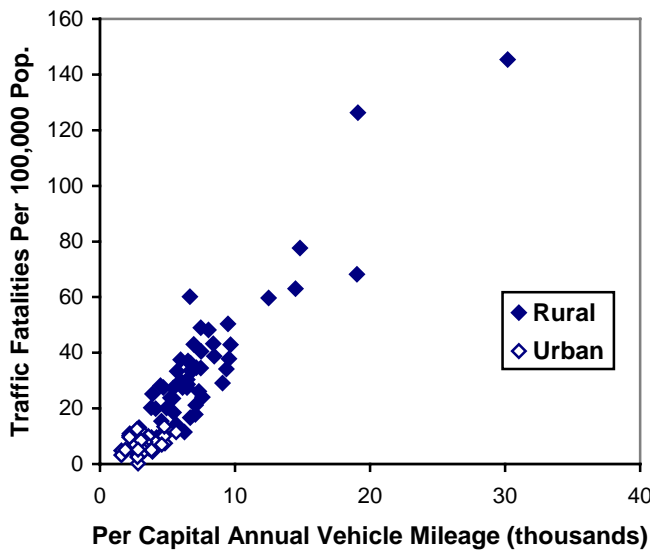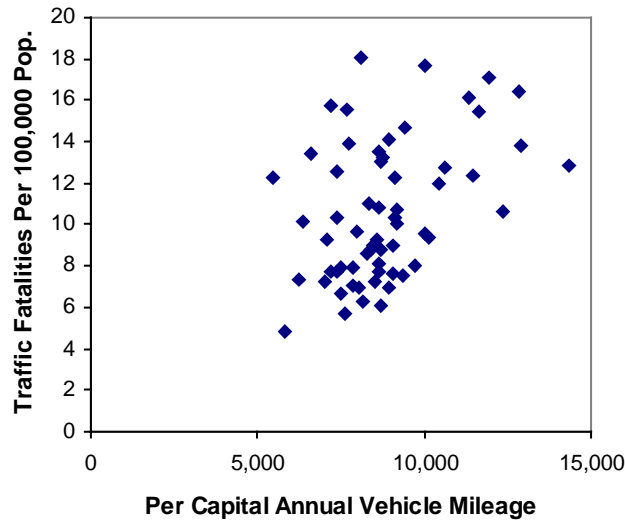

Per capita traffic fatalities increase with per capita mileage in U.S. regions.

Figures 6 and 7 shows the relationship between U.S. per capita mileage and traffic fatality rates. Figure 6 shows data for each state divided into urban and rural areas. As mileage increases so do fatality rates. High rural fatality rates probably reflect a combination of increased vehicle mileage and traffic speeds, slower emergency response, and differences in vehicles and driver behavior. A linear model applied to the data (Traffic Fatalities = -1.48534 + 4.90587 * Vehicle Mileage) has an 82.9% R-Squared, and a 0.9105 correlation coefficient, indicating a strong relationship between variables.

Figure 7 **Traffic Fatality and Mileage Rates in US Cities** (FHWA, 2002)

Per capita traffic fatalities increase with per capita mileage.

Insurance actuaries have long recognized that annual vehicle mileage is a significant factor in annual crash and claim rates (CAS, 1996, p. 35, 242 and 250; Butler, 1996). 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, apparently because it reduces annual vehicle use (Mercer, 1987). Elderly drivers tend to have high per-mile crash rates but low vehicle-year crash rates due to low annual mileage.

Figure 8 **Crash Rates by Annual Vehicle Mileage** (Litman, 1997)
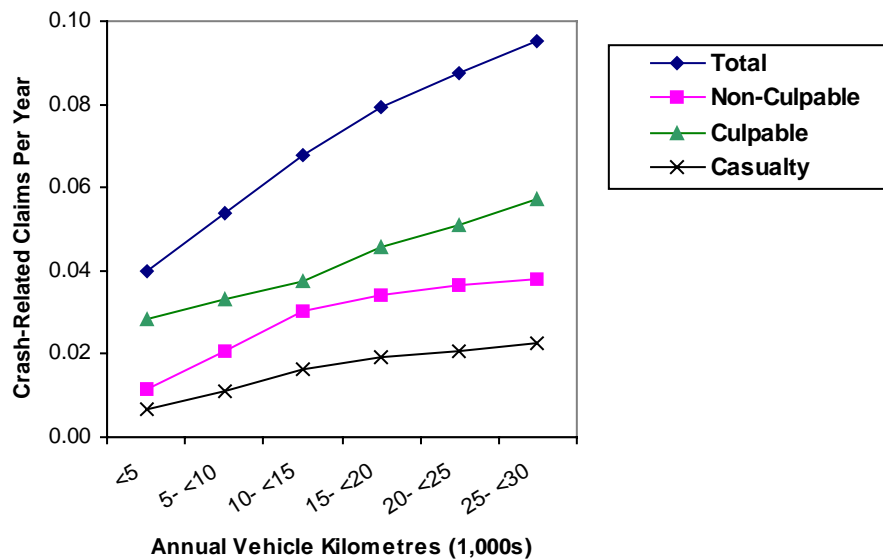
Claims per vehicle tend to increase with annual mileage. ("Culpable" means a driver was considered responsible for causing the crash. "Casualty" means a person was killed or injured.)

Figure 7 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, 1997). 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.

Several factors may partly offset this positive relationship between mileage and crashes (Janke, 1991; Maycock and Lockwood):

- Motorists who are higher-risk per vehicle-mile due to inexperience 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 can explain why per-mile crash rates decline with increased annual mileage, as indicated in Figure 8. These data indicate 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 for individual drivers is probably more linear. 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. Put differently, there is no reason to believe that miles driven at the beginning of the year are more dangerous than miles driven at the end of the year, although this is what is implied by a declining mileage-crash curve.

There is sometimes debate among insurance professionals over the relative importance of mileage as a risk factor. Some argue that annual vehicle mileage is less important than other factors such as driver age, vehicle type and location (Cardoso and Woll, 1993). However, whether mileage is more or less important than these other factors is irrelevant for evaluating mobility management safety impacts. When other factors are held constant (that is, for a particular motorist), annual mileage appears to have a major effect on annual crash rates, and mileage reductions can be expected to reduce per capita crashes.[3]

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[3] 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.

Reductions in total vehicle travel can cause proportionally larger reductions in *total* crash damages, since about 70% of crashes involve multiple vehicles. Each vehicle removed from traffic reduces both its chances of causing a crash *and* of being the target of a crash caused by another vehicle, and reducing multi-vehicle crash reduces multiple claims (Vickrey, 1968; Edlin and Karaca-Mandic, 2002). Even a perfect driver who never violates traffic rules increases safety by driving less, because this reduces their chance of being a target of another road user's mistake.

To illustrate this concept, Table 3 divides total crashes into four categories labeled A-D, depending on whether or not you are culpable, and whether the crash involves a single- or multiple-vehicles. We assume that you are an "average" driver, so you or mechanical problems with your vehicle cause about half of the crashes that you are involved in.

Table 3   Crash Categories

Your Fault (50%)		Others' Fault (50%)	
Single-Vehicle (30%)	Multi-Vehicle (70%)	Multi-Vehicle (70%)	Single-Vehicle (30%)
A	**B**	**C**	D

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. Bold categories (B & C) involve multiple vehicles and so cause greater costs per crash.

If you reduce your chances of *causing* a crash by 10% (perhaps by driving more cautiously or using a vehicle with better crash prevention features), you reduce crash categories A and B, and your total crash risk declines by 7%, since 30% of crashes that you are involved in are caused by other motorists' mistakes, and they 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' error (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 reduction in crash category C. If all motorists reduce their per-mile risk or their total mileage by 10% and other factors are held constant, total crashes should decline about 17% (10% + 7%), resulting from reductions in all crash categories, A-D. Table 4 summarizes these impacts.

Table 4   Summary of Risk Impacts

Type of Change	Crash Reduction Categories	Your Risk Reduction	Others Risk Reduction
You reduce your per-mile risk 10%.	A & **B**	7%	3.5%
You reduce your mileage 10%.	A, **B** & **C**	10%	7%
Others reduce their per-mile risk 10%.	**C** & D	3%	10%
Others reduce their mileage 10%.	A, **B** & **C**	7%	10%
Everybody reduces per-mile risk 10%.	A, **B**, **C** & D	17%	17%
Everybody reduces mileage 10%.	A, **B**, **C** & D	17%	17%

This table summarizes the categories of crashes reduced by various types of safety actions. Bold categories indicate crashes involving multiple vehicles.

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 multi-vehicle crash by 10% reduces total crash costs by about 20%, because each crash causes about twice the damage as a single-vehicle crash.

Put differently, reduced vehicle mileage in an area tends to reduce crashes by reducing traffic density (VMT per lane-mile). Multi-vehicle crash rates tend to increase with traffic density, which is why crash rates and insurance costs tend to be higher in urban areas compared with rural areas (Dougher and Hogarty, 1994; Clark and Cushing, 2004).

Some factors may partly offset this additional risk from increased traffic density. First, drivers may be more cautious when traffic density increases. Second, high levels of traffic density lead to congestion, which reduces speed and therefore crash severity, which is why fatality rates tend to be lower in urban areas, as indicated above (Zhou and Sisiopiku, 1997; Shefer and Rietvald, 1997). Third, increased mileage may justify roadway improvements, such as grade separation, which reduces per mile crash rates. However, most empirical evidence indicates that an increase in vehicle mileage causes a proportionately greater increase in crashes and crash costs, all else being equal, which suggests that a mobility management strategy that reduces overall mileage in an area can provide relatively large safety benefits.

Some studies have calculated the ratio between aggregate mileage and crash rates, fatality rates and insurance claim costs in a particular geographic area. 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.

Analyzing U.S. state-level traffic density and insurance claim costs, Edlin (1998) calculated marginal crash costs per additional vehicle-mile driven. He found that the elasticity of claim costs with respect to mileage is between 1.42 and 1.85, meaning that a 10% reduction in vehicle mileage reduces total crash costs between about 14% and 18%. Similarly, Edlin and Karaca-Mandic (2002) found that in high traffic density states, an increase in density dramatically increases claim costs, although this does not occur in low-density states. For example, they estimate that a each additional average-risk motorist added to the California traffic flow increases total insurance costs by $1,271-2,432. Their model indicates that U.S. national accident externalities (the incremental risk caused by each additional vehicle mileage) total $140 billion annually, averaging about 5¢ per vehicle mile.

This suggests that the elasticity of crashes to vehicle mileage is about 1.5 in urban areas with moderate to high traffic density, and declines to about 1.0 in low-density rural areas, all else being equal. Of course, these impacts are affected by the type of mileage reduced. All else being equal, a mobility management strategy that reduces average risk miles by 10% should reduce total crash costs by about 17% (the 10% reduction in risk to the motorists who reduce mileage, plus a 7% reduction in risk to another road users). A

strategy that reduces low-risk miles will cause a smaller reduction in total crash costs, while a strategy that reduces higher risk miles will cause a larger reduction. However, it would be wrong to conclude that safety benefits only result from reductions in relatively high-risk driving. Motorists considered low risk (i.e., they quality for "safe driver" insurance discounts) are involved in about half of all casualty crashes, and even faultless drivers reduce crash risk when they reduce mileage because they are less exposed to crashes caused by other road users' errors.

Certain risk factors deserve special attention when evaluating mobility management safety impacts:

1. Some mobility management strategies target urban commuting, which tends to have high crash rates but low fatality rates, due to high traffic densities. For example, a transit service improvement or incentive program is likely to reduce crashes and insurance claims proportionately more than fatalities.

2. 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 higher-risk, inexperienced drivers.

3. Traffic management strategies, such as traffic calming and new urbanist roadway design, reduce traffic speeds and therefore crash frequency and severity.

4. 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 may more frequently be allowed to continue driving because it is considered a necessity.

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 Ownership Reductions

Some mobility management strategies reduce vehicle ownership by changing the cost structure or improving alternatives. These include unbundled residential parking (residents pay directly for each parking space they use, rather than having parking costs included with vehicle rents), carsharing, transit improvements, pricing reforms, location-efficient mortgages (which improves mortgage options for home buyers who choose a less automobile-oriented location), and transit oriented development (VTPI, 2004). For example, unbundling residential parking typically reduces automobile ownership by 8-15% ("Parking Management," VTPI, 2004) and residents of transit-oriented developments tend to own about 30% fewer cars than otherwise comparable household in automobile-dependent neighborhoods ("Transit Oriented Development," VTPI, 2004).

Vehicle ownership reductions tend to reduce total vehicle mileage, although the vehicles given up tend have relatively low annual mileage, and some mileage may be shifted to other vehicles. In a typical case, a 2-driver household eliminates a second car that was driven 6,000 annual miles, and adds 1,000 annual miles to their primary vehicle, to rental vehicles, or to vehicle travel by friends who make additional chauffeur trips, resulting in a net reduction of 5,000 vehicle-miles for the household.

Pricing Reforms

A variety of transportation price reforms are advocated to achieve various objectives, including road and parking congestion reduction, pollution emission reductions, and increased fairness by charging motorists directly for the costs they impose (Litman, 2003; "Market Reforms," VTPI, 2004). These reforms can cause a variety of travel changes, including shifts in route, travel time, mode, destination and trip frequency ("Transportation Elasticities," VTPI, 2004), which have a variety of safety impacts. Individual pricing reforms are discussed below.

Road and Parking Pricing

Road pricing means that motorists pay a toll for driving on a particular road. *Parking pricing* means that motorists pay directly for using a parking space. Charging users direct for the costs of roads and parking facilities typically reduces demand by 10-30%. For example, a $1.50 per trip road toll typically reduces vehicle traffic by 20-30% compared with untolled roads ("Road Pricing," VTPI, 2004). When commuters must pay directly for parking or have a Cash Out option (they can choose cash rather than a parking subsidy) 15-25% typically shift to alternative modes ("Parking Pricing," VTPI, 2004). The city of London's £5 per day congestion fee introduced in February 2003 reduced vehicle trips in the city center by 20%, and crashes in the priced area declined about 25% (TfL, 2004). However, in some situations a portion of the reduced demand consists of travel shifted to other routes or times, which provides no safety benefit.

Fuel Price Increases

Fuel price increases can be justified as a way to fund transportation programs and as an energy conservation strategy ("Fuel Price Increases," VTPI, 2004). The long-term elasticity of fuel consumption with respect to price is about –0.7, so a 10% price increase causes a 7% reduction in fuel use, but about two thirds of this result from consumers purchasing more fuel efficient vehicles, and only about one third from vehicle mileage reductions. This means that a 10% increase in fuel price reduces mileage 2-3%.

There is debate concerning the safety impacts of more fuel efficient vehicles. Occupants of lighter vehicles in crashes with heavier vehicles or stationary objects, but this seems to be offset by lower crash frequency, reduced risk to others, and improved safety designs (CBO, 2003). To the degree that higher fuel prices reduce mileage they probably provide net safety benefits, while regulatory requirements to increase fleet vehicle efficiency reduce the per-mile cost of driving, which tends to increase per capita annual mileage and therefore total crashes (Litman, forthcoming).

Insurance Price Reforms

"Pay-As-You-Drive" pricing converts vehicle insurance premiums from a fixed cost into a variable cost by prorating existing premiums by average annual mileage, so insurance is priced by the vehicle-mile rather than the vehicle-year (Litman, 1997). This price structure gives motorists a new financial incentive to reduce their annual mileage based on their risk ratings. For example, a low-risk motorist who currently pays $300 annual premiums would pay about 2.5¢ per mile, and so is predicted to reduce their mileage about 5%, while a higher-risk motorist who currently pays $1,800 would pay 15¢ per mile, and so should reduce their annual mileage by 20%, since they receive greater savings with each mile reduced. This should provide relatively large safety benefits. The average per-mile premium would be about 5¢ per mile, which is predicted to reduce average annual vehicle mileage of affected vehicles by 10-12%. If fully implemented in an area, this should reduce traffic crashes by 12-15%.

As Vickrey (1968) points out, truly marginal pricing of vehicle crash risks would require an additional fee to account for the incremental risk imposed by each additional vehicle in the traffic stream, and for currently uncompensated crash costs (Litman, 2003). This could be imposed as a surcharge on mileage-based insurance premiums or as an additional roadway user charge. This should further reduce traffic crashes.

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. The safety impacts of these shifts are discussed below.

Traffic risks varies significantly by mode and how this risk is measured, as indicated in Table 5. For example walking has about ten times the *per mile* fatality rate as automobile travel, but about the same risk *per trip*, and only a 40% higher rate *per hour* of travel. If the choice is between walking and driving to a particular destination, driving is generally safer, but if the choice is between walking ten minutes to a local store or driving for fifteen minutes to a more distant shopping center, the user risks are similar.

Table 5   **User Fatality Rate By Mode** (DfT, 2003)

	Deaths	**Annual Miles**	**Deaths Per Bil. Miles**	**Annual Trips**	**Deaths Per Bil. Trips**	**Annual Hours**	**Fatalities Per Billion Hours**
Walk	767	192	*69*	245	*54*	64	*208*
Bicycle	129	34	*66*	14	*155*	5	*467*
Motorcycle/moped	609	36	*297*	3	*3,170*	1	*7,777*
Car/Van/Lorry	1,880	5,540	*6*	627	*52*	222	*147*
Public Transit	19	1,031	*0.32*	101	*3.3*	69	*4.8*
Totals	3,404	6,833	*8.7*	990	*59.8*	361	*163.8*

This table compares traffic fatality rates for various modes, using mileage, trips and hours as denominators. This only indicates risk to users, but not to others.

Table 5 only reflects deaths to the mode user. Comprehensive safety analysis also considers risks imposed on others. For this type of analysis, injuries that result from crashes between heavy and light vehicles (including motorcycles, bicycles and pedestrians), are generally assigned to the heavy vehicle on the assumption that the small vehicle would be less damaged had they crashed with a similar weight vehicle, since it is concerned with physical impacts, not the legal responsibility for the crash.

Table 6   **U.S. Transportation Fatalities, 2001**[4]

|	**Fatalities**			**Veh. Travel**	**Occupancy**	**Pass. Travel**	**Fatalities Rate**	
	User	Others	Totals	Bil. Miles		Bil. Miles	User	Others
Passenger Car	20,320	3,279	23,599	1,628	1.59	2,589	7.9	1.3
Motorcycle	3,197	19	3,216	9.6	1.1	10.6	303	1.8
Trucks – Light	11,723	3,368	15,091	943	1.52	1,433	8.2	2.3
Trucks – Heavy	708	4,189	4,897	209	1.2	251	2.8	16.7
Intercity Bus	45		45	7.1	20	142	0.3	-
Commercial Air						-	0.3	
Transit Bus	11	85	96	1.8	10.8	19	0.6	4.4
Heavy Rail	25	6	31	0.591	24	14	1.8	0.4
Commuter Rail	1	77	78	0.253	37.7	9.5	0.1	8.1
Light Rail	1	21	22	0.053	26.8	1.4	0.7	14.8
Pedestrians	4,901	0	4,901	24.7	1	25	198	-
Cyclists	732	0	732	8.9	1	8.9	82.2	-

This table indicates deaths and per capita traffic fatality rates for various modes

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[4] Based on BTS, *National Transportation Statistics* (www.bts.dot.gov/publications/national_transportation_statistics/2003/index.html), 2003, Tables 1-32, 2-1 and 2-4; APTA, *Safety Summary By Mode* (www.apta.com/research/stats/safety/safesumm.cfm), 2003. Pedestrian and cycling mileage is based on FHWA, *National Bicycling and Walking Study Ten Year Status Report*, (www.fhwa.dot.gov/environment/bikeped/study), 2004, assuming 0.7 mile average walking trip and 2.3 mile average cycling trip length. Light truck "Others" deaths are calculated based on a portion of pedestrian deaths, plus 1,282 additional automobile passenger deaths over what would occur if car/truck collisions had the same car occupant fatality rate as car/car collisions, based on analysis by Gayer, 2001. This is conservative because it does not account for the higher per mile collision involvement rates of light trucks compared with passenger cars.

Figure 9 shows "User" and "Other" fatality rates per billion miles of travel for various modes. This represents a lower-bound estimate of "Other" fatalities for passenger cars because it ignores the contribution a vehicle may make to deaths in similar or larger size vehicles, including crashes caused when a larger vehicle take evasive action to avoid crashing into a smaller vehicle. Perry (2004) develops a detailed analysis of the external crash costs of various vehicle types. His model assumes that the average portion of external crash costs each motorist imposes on others in multi-car accidents ranges from 0% up to $1/(n-1)$ of the injuries, where *n* is the number of vehicles in the crash (for example, a vehicle can be considered responsible for up to 50% of the crash costs in a two-vehicle crash, and up to 33% in a three vehicle crash). Applying this approach would significantly increase the allocation of "Others" fatalities to passenger cars.

Figure 9   **Transport Fatalities, 2002**
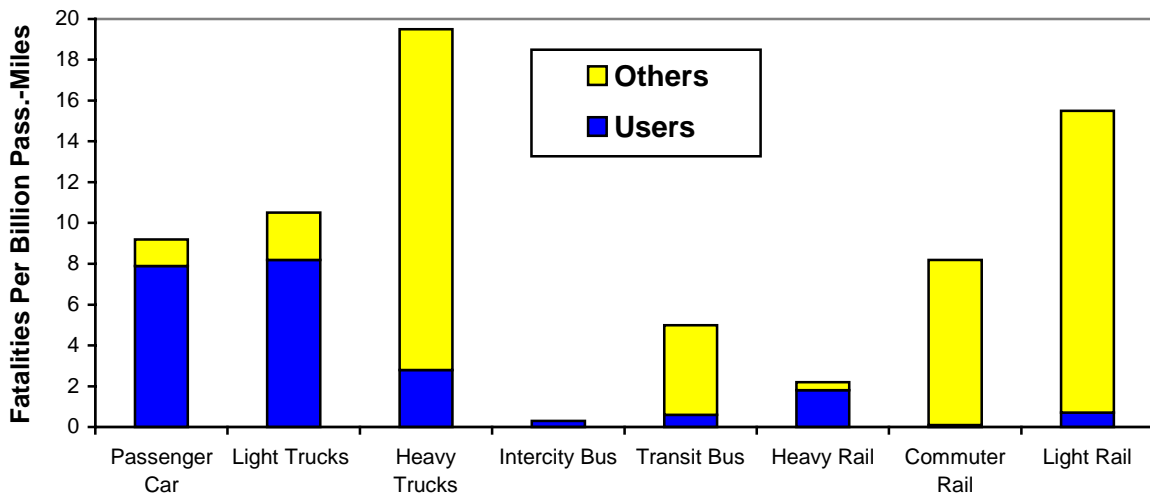
Transit travel tends to have lower crash rates than automobile travel, even taking into account risks to other road users.

Transit

Transit is a relatively safe travel mode, particularly for users, as indicated in Figure 10.[5] Transit passengers have about one-tenth the fatality rate as car occupants, and even considering external risks, transit causes less than half the total deaths per passenger-mile as automobile travel. Transit crash casualty rates per passenger-mile depend on transit vehicle occupancy (passengers per vehicle-mile). Total crash rates per passenger-mile (including risks to transit vehicle occupants and other road users) are relatively high in some jurisdictions due to low average transit vehicle occupancies (in some cases exceeding automobile crash rates) and because a large portion of transit vehicle mileage occurs in congested urban conditions, but as transit ridership increases crash casualty rates per passenger-mile decline. A mobility management strategy that encourages transit ridership and increases average transit vehicle occupancy imposes little incremental external risk and reduces passenger-mile crash rates.

Figure 10   **U.S. Traffic Deaths** (Litman, 2004b)
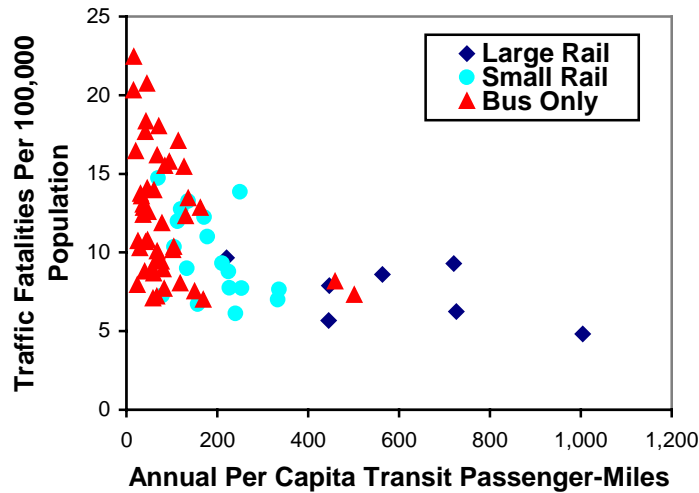

Per capita traffic fatalities (including automobile occupants, transit occupants and pedestrians) tends to decline with increased transit ridership.

Total per capita crash rates tend to decline as transit ridership increases in a community, and are particularly low in cities with large rail transit systems as indicated in Figure 10. International data also indicate per capita traffic deaths decline with increased transit ridership, as indicated in Figure 11.

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[5] The exception is U.S. light rail transit (LRT), which has unique accident risks (TCRP, 2001). They operate in dense urban conditions where crash risk is high. Other travel modes also have a relatively high crash rates under these conditions. Many LRT systems are new, and so have relatively low ridership, and limited experience by both operators and motorists. Some "accidental" rail transit deaths are probably suicides, and since the number of LRT deaths is small, even a few miss-categorized deaths significantly increases the fatality rate.

Figure 11 **Traffic Fatalities Vs. Transit Travel** (Kenworthy and Laube, 2000)
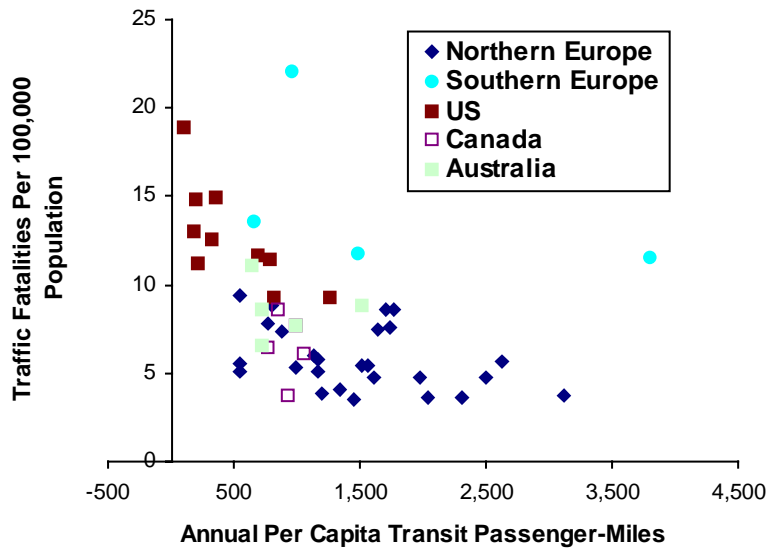
International data indicate that crash rates decline with increased transit ridership.

These traffic fatality reductions result not just from automobile vehicle-miles shifted to transit passenger-miles, but also from the leverage effects transit can have on transportation and land use patterns (Litman, 2004b). Residents of cities with high quality transit tend to own fewer automobiles, drive less (due to reduced vehicle ownership and more compact and mixed land use patterns), have lower traffic speeds (due to more compact urban development), and have less high-risk driving (for example, teenagers and elderly people may be less likely to have a drivers license and own a vehicle in communities with better travel alternatives). The traffic safety impacts of more accessible land use patterns are discussed in more detail later.

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 reducing traffic volumes. 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). Overall, ridesharing should reduce crash rates, but this will be partly offset by increased injuries per crash.

For example, if increased ridesharing caused average vehicle occupancy to increase 10% and mileage to declined by 10%, and the elasticity of crashes to mileage is 1.5 as suggested earlier, total crashes should decline by 15%, but the casualty rate per crash should increase by 10%, so total casualties would only decline by about 5%.

Nonmotorized Transport

Walking and cycling tend to have higher user per-mile crash rates than motorized modes, as indicated in Table 5. But mobility management programs that shift travel from motorized to nonmotorized modes can cause much smaller incremental risk because:

1. Nonmotorized travel imposes minimal risk to others.

2. 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.

3. 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.

4. Some walking and cycling promotion programs include education and facility improvements that reduce per-mile bicycle crash rates.

5. Walking and cycling provide health benefits, including physical fitness and air pollution emission reductions, that may offset increased accident risks.

The incremental risk for responsible pedestrian or cyclist who observes traffic rules and takes precautions such as using a light at night and a helmet (for cyclists) is likely to be much lower than indicated by average per-mile fatality rates, and offset by reductions in risk to other road users and other health benefits.

Figure 12 **Traffic Fatalities Vs. Non-Motorized Transport** (US Census, 2000)
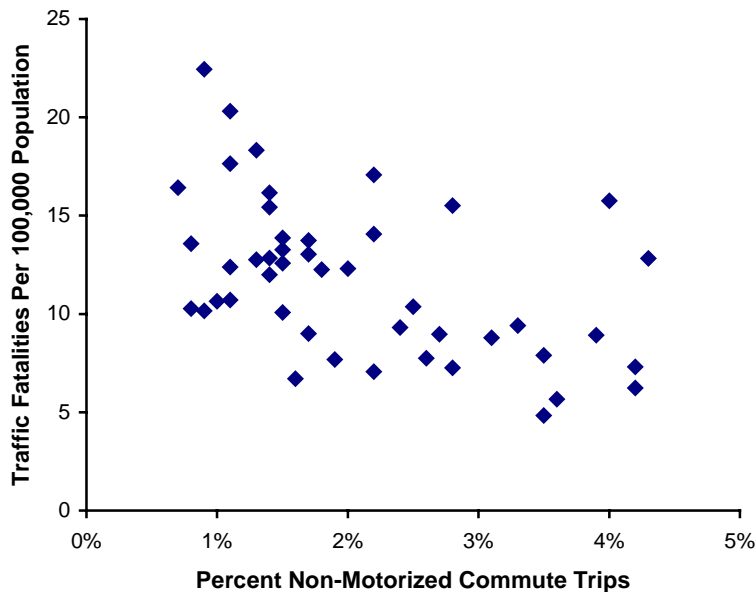
Per capita traffic fatality rates tend to decline in U.S. metropolitan regions as the portion of nonmotorized urban travel increases.

Empirical evidence indicates that at the community level, shifts from driving to nonmotorized modes tends to reduce total per capita traffic casualty rates, and per mile traffic casualty rates for pedestrians and cyclists. Both U.S. and international data indicate that per capita traffic fatality rates tend to decline as walking and cycling increase in a community, as indicated in figures 12 and 13. In developed countries with high rates of nonmotorized travel, such as Germany and the Netherlands, 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 (Pucher and Dijkstra, 2000).

Figure 13   **Traffic Fatalities Vs. Non-Motorized Transport** (Kenworthy and Laube, 2000)
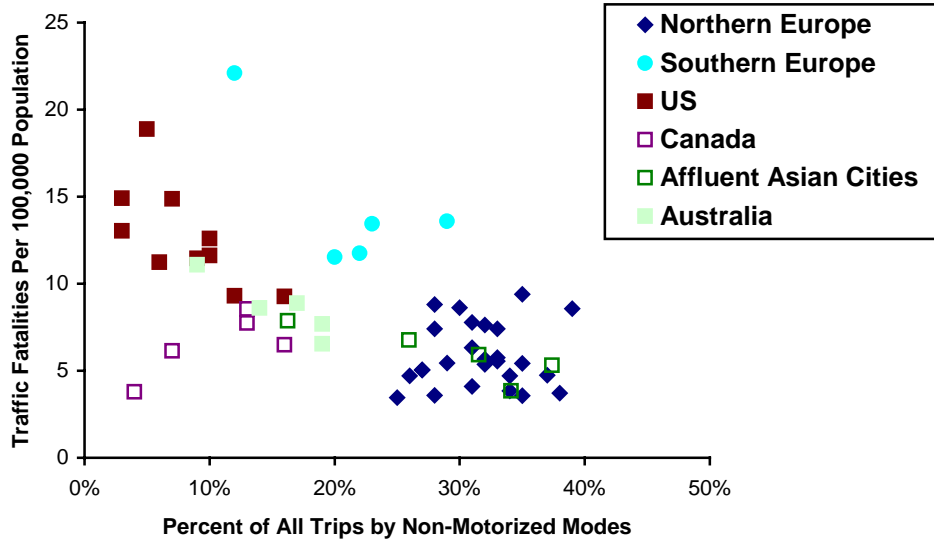
International data indicate that per capita traffic fatality rates tend to decline in a city as the portion of nonmotorized travel increases.

Wardlaw (2001) finds that in a variety of geographic conditions, doubling cycling mileage only increases cycling deaths by 25%. He hypothesizes that this results from a combination of reduced automobile travel (which reduces risk to cyclists), increased cycling skill, and increased caution by drivers. Jacobsen (2003) also found that per capita collisions between motorists and nonmotorized road uses decline in areas with higher rates of nonmotorized travel. He calculates that the number of collisions between motorists and nonmotorists increases at roughly the 0.4 power of the amount of walking and cycling that occurs in a community (e.g., doubling nonmotorized travel increases 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 amount of nonmotorized travel (e.g., risk of a pedestrian being hit by a motorists declines 34% if walking and cycling double in a community).

Nonmotorized travel provides physical exercise which can have substantial health benefits (AJHP, 2004; "Health and Fitness," VTPI, 2004). Inadequate physical exercise and excessive body weight are increasing problems that results in a variety of medical problems, including cardiovascular diseases, bone and joint injuries, and diabetes. About ten times as many people die from these medical problems than from traffic accidents.

Although there are many ways to be physically active, increased walking and cycling are among the most practical and effective, particularly for inactive and overweight people. Recent studies indicate that residents of more walkable communities exercise more and are less likely to be overweight than residents of automobile-oriented communities (Ewing, Schieber and Zegeer, 2003; Frank, 2004).

In summary, although nonmotorized travel is more hazardous to users per mile of travel, for various reasons increased nonmotorized travel tends to reduce total traffic risk in a community. There is no evidence that shifting travel from driving to nonmotorized modes increases total public health risks, especially if traffic safety education and facility improvements are provided. Any increase in risk that does occur is probably more than offset by physical fitness benefits.

Mobility Substitutes
Mobility substitutes include telework and delivery services. These can reduce vehicle travel and therefore traffic accidents, although there may be rebound effects that offset a portion of mileage reductions and associated safety benefits ("Telework," VTPI, 2004). Telecommuters often make additional trips for errands that they would otherwise perform while commuting. Some employees choose more distant worksites or more isolated home locations if they are allowed to telecommute. For example, if allowed to telecommute three days a week an employee might move from an urban home with a 50 mile commute to a rural home with a 100 mile commute. Their 60% reduction in commute trips is offset by a 100% increase in commute distance, resulting in just a 20% net reduction in total commute mileage, and this may be offset further if the employee makes additional errand trips during commuting days or chooses a more automobile-dependent home location.

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 (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
Traffic speed reductions tend to reduce collision rates and crash severity, and are particularly effective at reducing injuries to pedestrians and cyclists (Leaf and Preusser, 1998 ; "Speed Reductions," VTPI, 2004). Traffic calming (roadway design strategies to reduce traffic speeds on a particular roadway) and increased traffic law enforcement tends to increase safety ("Traffic Calming," VTPI, 2004). 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%).

Smart Growth Land Use Management

S*mart growth* (also called *new urbanism* and *transit oriented development*) consists of
land use development policies that more compact, mixed use, multi-modal communities
("Smart Growth" VTPI, 2004). This is an alternative to dispersed, automobile-dependent,
urban fringe development, commonly called *sprawl*.

Smart growth land use patterns have various impacts on travel behavior and traffic safety
("Land Use Impacts On Transportation," VTPI, 2004). Increased density tends to
increase crash rates per vehicle-mile, but reduces per capita traffic fatalities. Ewing,
Schieber and Zegeer (2003) that per capita traffic fatality rates increase with the degree of
sprawl in a community (Figure 14). They estimate that each one percent increase in their
Smart Growth index reduces the area's traffic fatality rate by 1.5%.

Figure 14 **Annual Traffic Death Rate** (Ewing, Schieber and Zegeer, 2003)
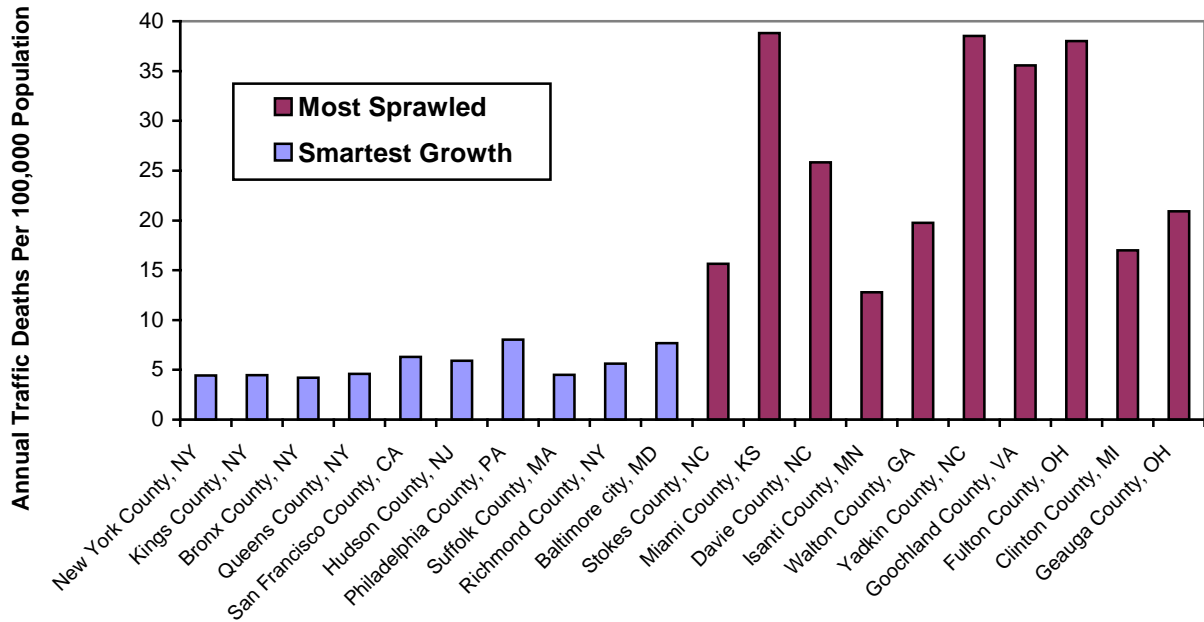
The ten U.S. communities ranked least sprawled have per capita annual traffic fatality rates that
average a quarter of those in the most sprawled communities.

Several factors contribute to these safety impacts. Smart growth reduces per capita
vehicle mileage, but only 10-20%, which does not fully explain the traffic fatality
reductions. Other factors probably include lower traffic speeds due to lower roadway
design speeds and increased congestion, more caution by drivers as traffic density
increases, and greater willingness by authorities to revoke driving privileges of higher-
risk drivers. Conversely, in automobile dependent communities people drive more, drive
faster, teenagers obtain drivers licenses and personal vehicles at a younger age, and
authorities are hesitant to revoke the driving privileges of high-risk motorists, because
they have few transportation alternatives.

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 traffic fatalities and homicides (Lucy, 2002).

Vehicle Use Restrictions

Some communities have vehicle use restrictions, for example, *No-Drive Days* during which a certain portion of vehicles are prohibited from being used in a particular urban area, and prohibitions on driving on certain streets at certain times. However, these may shift vehicle travel to other times and locations, rather than reducing total vehicle mileage. For example, motorists may simply defer automobile errand trips from No-Drive Days to other days, and detour around car-free districts, resulting in no reduction in mileage or crash risk. Only if such restrictions are part of an overall program to improve travel options and create more accessible land use patterns are they likely to reduce total traffic risk.

Safety Impacts Summary

Table 7 summarizes how various mobility management strategies affect travel patterns and the resulting safety impacts. A particular mobility management program may cause more than one type of travel change. For example, pricing reforms reduce total vehicle mileage, in part by shifting automobile travel to alternative modes.

Table 7   **Mobility Management Safety and Health Impact Summary**

| MM Strategies	Travel Changes	Safety Impacts
Pricing reforms (road pricing, parking pricing, increased fuel taxes, etc.).	Reduces vehicle mileage.	Moderate to large safety benefits. Vehicle mileage reductions generally cause proportional or greater reductions in total crash damages.
PAYD Insurance.	Reduces mileage in proportion to motorist risk class.	Large potential safety benefits. Reduces total traffic and gives high-risk motorists an extra incentive to reduce mileage.
Transit Improvements, HOV Priority, Park & Ride	Shifts automobile travel to transit	Moderate to large safety benefits. Shifts from automobile to transit reduce crash rates, and additional benefits are possible if major transit improvements provide a catalyst for less automobile-dependent land use patterns.
Ridesharing, HOV Priority	Shifts to single occupant travel to ridesharing	Moderate safety benefits. Increases safety due to reduced vehicle traffic, but crashes that occur may involve more victims.
Walking and Cycling Improvements, Traffic Calming	Shifts motorized travel to nonmotorized modes	Mixed safety impacts. Can increase per-mile risk to people who shift, but reduces risk to other road users, reduces total person-miles, increases driver caution, and can provide significant health benefits.
Telework, Delivery Services	Reduces total vehicle travel	Modest safety benefits. Reduced vehicle mileage reduces crashes some benefits may be offset by rebound effects.
Flextime, Congestion Pricing	Shifts travel from peak to off-peak	Mixed. Reducing congestion tends to reduce crashes, but increased speed increases crash severity.
Traffic Calming, Speed Enforcement	Reduces traffic speeds	Large safety benefits where applied. Increases safety by reducing crash frequency and severity, and reducing total vehicle mileage.
Land use management (Smart Growth, New Urbanism, etc.)	Reduces per capita vehicle travel and traffic speeds.	Large safety benefits. Increases safety by reducing per capita vehicle travel. Increases congestion, which increases crash frequency but reduces crash severity.
Time and location driving restrictions.	Vehicle Use Restrictions	Mixed. May shift vehicle travel to other times and routes, providing no safety benefit.

This table summarizes the safety impacts of mobility management strategies.

Mobility Management Benefit Evaluation

Mobility management programs are currently evaluated primarily on their cost effectiveness for achieving one or two specific objectives. For example, transportation agencies generally evaluate mobility management based on its ability to reduce road congestion, and environmental agency generally evaluate it based on its ability to reduce pollution emissions. Other impacts are often overlooked. Traffic safety impacts are generally given little consideration in mobility management evaluation.

Various studies have *monetized* (measure in monetary value) transportation costs, including crash costs (Miller, 1991; Murphy and Delucchi, 1998; Wang, Knipling and Blincoe, 1999; Litman, 2004a). Crash costs are one of the largest categories of societal costs associated with motor vehicle use. 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 15.[6]

Figure 15   **Costs of Motor Vehicle Use in the U.S.** (Litman, 2004a)
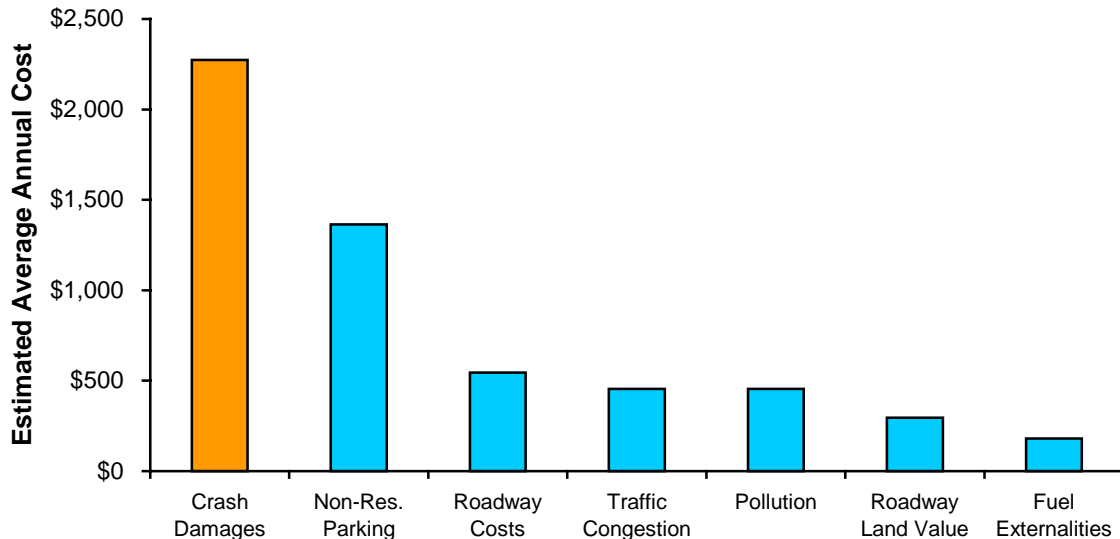
This figure illustrates the estimated magnitude of various transportation costs. Crash costs (including market and non-market, internal and external costs) are the largest category, far greater than congestion or pollution costs.

The relative magnitude of these costs has important implications for transportation planning. 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 is a poor investment. On

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[6] Some studies give lower total estimates of crash costs because they are based on a "human capital" methodology, which only considers people's economic productivity, rather than a comprehensive analysis based on willingness-to-pay to reduce risks, including non-market values. Most experts agree that willingness-to-pay is the appropriate methodology for valuing safety programs that avoid damages. A human capital methodology may be more appropriate for damage compensation.

the other hand, a congestion reduction strategy provides 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%.

Current transport planning practices that give little or no consideration to safety impacts of changes in vehicle mileage. This tends to overvalue roadway and vehicle improvements that increase vehicle mileage (such as highway capacity expansion which induce vehicle travel on a particular roadway, and vehicle fuel efficiency and safety improvements that increase per capita vehicle mileage), and undervalues mobility management programs that reduce vehicle mileage.

For example, 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 (2001b) points out that, although highway capacity expansion is often justified based on projected crash reductions, total road safety will only increase if the roadway improvement avoids increasing traffic volumes and speeds. Research by Noland (2003) suggests that highway improvements tend to increase crashes overall, apparently due to increased vehicle traffic mileage and speed.

Similarly, there has been considerable debate over the value of corporate fuel efficiency standards, which force vehicle manufactures to sell more fuel efficient vehicles. A key issue in this debate is the effect these standards have on traffic safety due to their impacts on vehicle size and crash protection (CBO, 2003). However, there has been little debate over their traffic safety impacts due to increased mileage (increased fuel efficiency reduces per-mile vehicle operating costs, leading to increased average annual mileage), although this effect is probably a larger (Litman, forthcoming).

Mileage related safety impacts are also generally ignored in the evaluation of land use policies, such as optimal parking standards (higher standards encourage vehicle ownership and use, and create more dispersed, automobile-dependent land use patterns), the consolidation of public facilities such as schools and recreational centers (more centralized facilities require more driving, and encourage families to purchase vehicles for their teenage children), debates between smart growth and sprawl, and countless other public policy decisions that directly or indirectly affect the amount of vehicle travel that will occur in an area.

How Much Safety Can Mobility Management Provide?

It is interesting to speculate how much traffic safety mobility management can provide cost effectively, and how this compares with other safety strategies. Below are 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 mileage by 10-12% and crashes by 12-15%.

b. Parking Pricing and Parking Cash Out tend to reduce automobile trips by about 20% where applied. Assuming that these strategies could be applied to half of all parking activity, crashes would decline approximately 10%.

c. Personalized marketing programs and targeted improvements in walking, cycling and transit service have successfully reduced local vehicle trips by 7-14%, suggesting that such programs could reduce crashes 5-10%.

d. London's congestion pricing program reduced crashes within that charge area about 25%. Assuming that 20% of all vehicle trips face congestion, this implies that congestion pricing could reduce total crashes about 5%.

e. Residents of smart growth communities tend to drive 15-25% fewer miles and have 20-40% fewer per capita crash fatalities than residents of conventional, automobile-oriented communities.

Care is needed when calculating the cumulative impacts of multiple strategies. Total impacts are multiplicative not additive, because each additional factor applies to a smaller base. For example, if one factor reduces travel by 20%, and a second factor reduces travel an additional 15%, their combined effect is calculated 80% x 85% = 68%, a 32-point reduction, rather than adding 20% + 15% = 35%. This occurs because the 15% reduction applies to a base that is already reduced 20%. On the other hand, many strategies have synergistic impacts (total impacts are greater than the sum of their individual impacts). A mobility management program that incorporates a variety of cost-effective strategies (e.g., road and parking pricing, improved travel options, and smart growth land use policies) can be expected to reduce per capita crashes 20-30% or more where applied.

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). 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 provide crash reductions comparable in magnitude to many well-known safety strategies, while also providing additional benefits from congestion reductions, road and parking facility cost savings, consumer benefits, environmental quality improvements, and exercise-related health benefits.

Are There Offsetting Factors?

Some people are skeptical of mobility management benefits. They concede that reducing vehicle travel can reduce problems such as accidents and traffic congestion, but believe that travel reductions are difficult to accomplish, or argue that the benefits are offset by reduced consumer welfare and economic productivity. After all, motorists must consider their incremental crash risk worth their incremental benefits, so policies to discourage driving must make them worse off overall. Similarly, automobile travel is associated with economic development, so reductions in vehicle ownership and use must be harmful to the economy. However, these argument fails to consider several important issues.

First, there is evidence that at the margin (that is, compared with current travel patters), many motorists would prefer to drive somewhat less and rely more on travel alternatives, provided that they have suitable options and incentives ("TDM Marketing," VTPI, 2004).

Second, many mobility management strategies reduce travel by giving consumers better options or positive incentives. For example, consumers who reduce their automobile travel in response to improved transit services or cycling conditions, or in response to a positive financial incentive such as Parking Cash Out, must be better off or they would not make the change. Even financial disincentives may have neutral consumer impacts overall if they reduce other consumer costs. For example, road and parking fees are simply an alternative way to finance roads and parking facilities, and so these fees are offset by reductions in taxes, rents or other funding sources.

Third, market distortions create a disconnect between the incentives that consumers face and what is socially optimal. Virtually all economists agree that automobile travel is underpriced to some degree, taking into account congestion externalities, underpricing of roadway and parking facility use, and uncompensated accident and environmental damages (Litman, 2003). Until each of these costs is internalized, consumers will tend to drive more than is economically optimal, so disincentives to driving are justified on second best grounds (that is, to deal with a problem if optimal pricing is not possible).

If market incentives are correctly applied, the travel reduced consists of lower-value trips that consumers are most willing to forego when given modest incentives (Market Principles," VTPI, 2004). If mobility management programs allow consumers to decide which automobile trips to take and which to forego, and include appropriate travel options such as transit improvements and rideshare services, net losses to consumers tend to be small.

Fourth, part of the reason that consumers drive is that alternative modes are stigmatized or considered unsafe. In many communities, walking, cycling and transit are uncommon activities that lack respect. To the degree that mobility management programs increase use of alternative modes by middle-class people, such programs make them safer and more socially acceptable, further increasing their use. This makes consumers better off overall.

Fifth, out of ignorance or psychological denial, most motorists understate their true crash risk. Vehicle travel is a common activity, and the risk of any particular trip or mile of travel seems miniscule. Most drivers consider their ability to be above average, and their crash risk below average. Many take pride in their driving ability, and so tend to be offended by suggestions that their driving is risky to themselves or others. It is therefore not surprising that through a combination of optimism, denial and externalization of costs, drivers are not usually influenced by the crash risks they impose on themselves and others, even if overall, it is one of the highest costs associated with motor vehicle travel.

Sixth, although increased vehicle ownership and travel are associated with increased wealth, there is little evidence that high levels of vehicle travel cause wealth or increase economic productivity. On the contrary, there is evidence that appropriate mobility management strategies (e.g., efficient pricing, improved travel options, more accessible land use patterns, etc.) improve economic efficiency and productivity ("TDM and Economic Development," VTPI, 2004).

This is not to say that mobility management programs always make individual consumers better off. Some involve negative incentives that reduce the affordability or convenience of driving for a particular trip, although these are offset by increased convenience by other motorists and other modes, and revenues streams that can offset other consumer charges (for example, High Occupancy Vehicle priority strategies may increase automobile congestion delays but reduce delays to transit and rideshare occupants, and road and parking pricing simply substitutes for other taxes and fees used to fund these facilities). But it would be wrong to assume that consumers are necessarily worse off overall. Each program must be evaluated individually ("TDM Evaluation" VTPI, 2004). A well-designed mobility management programs based on market principles and sensitive to consumer needs can reduce a significant amount of driving while providing net benefits overall.

Conclusions

Past traffic safety programs have significantly reduced per-mile crash rates. This suggests that such programs are effective at improving safety and should be continued. However, increased vehicle mileage has offset much of these gains. Per capita crash risk has declined relatively little despite major improvements in roadway and vehicle designs, motorist behavior, emergency response and medical treatment. Traffic crashes continue to be a major health risk. When evaluated in this way, new approaches are justified to improve traffic safety.

Mobility management includes various strategies that change travel behavior to increase transportation system efficiency. It can provide a variety of benefits including traffic congestion reductions, road and parking facility cost savings, consumer cost savings, energy conservation, pollution reduction, and support for various land use and equity objectives. Mobility management also tends to increase traffic safety and public health.

Mobility management safety impacts are affected by the travel changes they cause. Although difficult to predict with precision, available information suggests the following effects:

1. Mobility management strategies that reduce overall vehicle travel probably provide proportional or greater reductions in crashes. Available evidence suggests that a 10% reduction in mileage in an area provides a 10-14% reduction in crashes, all else being equal.

2. 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.

3. Strategies that shift travel from driving to transit or ridesharing tend to provide medium to large safety benefits, depending on specific conditions.

4. Strategies that shift automobile travel to nonmotorized modes (walking and cycling) may increase per-mile risk for the people who change mode, but tends to reduce total crashes in an area due to reduced trip length and reduced risk to other road users. Nonmotorized travel also provides health benefits that may more than offset any increased risk to users.

5. 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.

6. Strategies that reduce traffic speeds tend to reduce per-mile crash frequency and severity, particularly in congested urban areas with high pedestrian traffic.

7. Smart growth land use management strategies may increase crash rates per lane-mile (due to increased traffic density and congestion) but tend to reduce per capita casualties due to reduced vehicle travel, lower traffic speeds and more restrictions on higher-risk drivers.

8. Vehicle traffic restrictions may reduce crashes if they reduce total vehicle mileage, but may do little to improve safety overall if they simply shift vehicle travel to other times or routes.

9. Safety impacts are affected by specific demographic and geographic factors. For example, automobile to cycling mode shifts may reduce crashes by responsible adults in communities with good cycling conditions, but may increase crashes if those affected by less responsible or if cycling conditions are hazardous.

Crash damages are one of the largest categories of societal costs of motor vehicle use, much 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 crash costs by 3% provides no overall benefit to society. 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. The traffic safety impacts that result from 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 reduce mileage. Yet, increased safety appears to be one of the largest potential benefits of mobility management, and mobility management programs are likely to be among the most cost effective ways to improve traffic safety.

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