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"Efficiency - Equity - Clarity"

Safe Travels

Evaluating Mobility Management Traffic Safety Impacts

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Abstract

This report investigates the relationships between mobility (the amount people travel) and crash risk, and the traffic safety impacts of *mobility management* strategies that change travel patterns to increase transportation system efficiency. Although many factors affect traffic crash rates, evidence summarized in this report indicates that all else being equal, per capita traffic crash rates increase with per capita vehicle travel, and that mobility management strategies tend to provide safety benefits. Strategies that reduce per capita vehicle travel tend to reduce overall crash risk. Mode shifting tends to reduce per capita crash rates by reducing risk per mile and total mileage. Shifting vehicle travel from more- to less-congested conditions tends to reduce crash frequency but may increase crash severity due to higher traffic speeds. Smart growth land use policies tend to reduce crash severity and fatality rates, although crash frequency may increase due to increased traffic density. Strategies that reduce traffic speeds provide significant safety benefits. Conventional traffic risk analysis tends to understate the safety impacts of changes in mileage. This analysis indicates that mobility management is a cost effective traffic safety strategy, and increased safety is one of the largest benefits of mobility management.

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Todd Litman & Steven Fitzroy © 2005-07

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Introduction

Public policies affect people’s travel patterns, which affects their exposure to traffic crashes. Policies that reduce per capita vehicle travel, reduce traffic speeds, and improve travel options, particularly for higher risk drivers (younger and older drivers, people out drinking alcohol), can significantly reduce traffic risk.

In total, residents of more accessible, multi-modal, *smart growth* communities have about a quarter the per capita traffic casualty rate in more automobile-dependent communities. Many families move to automobile-oriented communities because they want a safe and healthy to raise their children. They are mistaken. Overall, people are safer and healthier in urban neighborhoods than in automobile-dependent sprawl because any increase in homicide risk in urban areas (which are actually small or non-existent) is more than offset by higher traffic fatality risks in suburban and rural areas (Durning 1996; Lucy 2002 and 2003; Frumkin, Frank and Jackson 2004; Ewing and Dumbaugh 2009).

Traffic crashes are a significant problem, causing tens of thousands of deaths, millions of injuries and hundreds of billions of dollars in economic costs annually (Miller 1991; Litman 2006; WHO 2004). For people aged 1 to 33, traffic crashes are the single greatest cause of fatalities and disabilities, and therefore a major cause of potential years of productive life lost (CDC 2003; NHTSA 2005). Many consumers consider safety an important consideration when choosing vehicles and willingly pay a premium for optional safety features. Safety is also a paramount consideration in roadway design and operations. Yet, safety is not usually a consideration when evaluating policies that affect *how much* vehicle travel occurs or to justify 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. These are an increasingly common response to urban traffic congestion and pollution problems. For example, the Congestion Management and Air Quality (CMAQ) program and many regional transport plans include mobility management components.

Table 1 Mobility Management Strategies (VTPI, 2004)

Improves Transport Options	Pricing Incentives	Land Use Management	Implementation Programs
Transit improvements	Congestion pricing	Smart growth	Commuter trip reduction programs
Walking and cycling improvements	Distance-based fees	New urbanism	School and campus transport management
Rideshare programs	Parking cash out	Parking management	Freight transport management
Flextime	Parking pricing	Transit oriented development	Tourist transport management
Telework	Pay-as-you-drive vehicle insurance	Car-free planning	Marketing programs
Carsharing	Fuel tax increases	Traffic calming	
Guaranteed ride home			

This table lists various mobility management strategies.

This report explores the relationships between mobility (the amount people travel) and crash risk, the potential traffic safety impacts of mobility management, and the degree that these impacts are considered in conventional transport planning. It builds on an extensive body of previous research concerning the relationships between vehicle travel and traffic risk (Vickrey 1968, Wilde 1984; Haight 1994; Dickerson, Peirson and Vickerman 1998; Andrey 2000; Edlin and Karaca-Mandic 2002 and 2006; Lawrence Frank & Company 2008).

Table 2 Factors Affecting Traffic Casualty Rates

User Behavior	Vehicles	Facilities	Mobility
Attitudes	Road worthiness	Road design & maintenance	Per capita vehicle travel (exposure)
Impairment	Occupant restraints	Pedestrian and cycling facilities (separation from traffic)	Mode split
Seatbelt and helmet use	Other safety devices	Traffic speeds	
	Crash-protection design	Emergency response and medical care	

Many factors affect per capita traffic casualty rates. Some affect crash frequency, others crash severity (the risk of injury or death when a crash occurs), or emergency response and medical care.

This issue is both simple and complex. It is simple because, all else being equal, vehicle mileage undoubtedly affects crash frequency. However, it is complex because many other factors also affect crash rates (Table 2), and mobility management strategies have various travel impacts (Table 3) with various impacts on crash rates and severity. Different mobility management programs 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 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 3 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.
Walking and cycling 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.

This issue is controversial. Many people dislike the idea that mileage itself is a significant risk factor and that mobility management is an appropriate way to reduce crash risk. Traffic safety experts often argue that “there are no accidents,” claiming that every crash has a cause that could be prevented, allowing virtually risk-free travel. Most devote their careers to identifying and mitigating specific risk factors, such as impaired driving and risky roadway conditions, and take pride in the effectiveness of their efforts. Similarly, transportation planners and engineers, who work to accommodate increased vehicle travel and reduce crash risk, also tend to resist the idea that their efforts are ineffective and may increase overall traffic risk. Individual motorists consider safe driving a point of pride – the vast majority of drivers consider their driving skills “above average” – and so find insulting the idea that their own driving is dangerous and reducing their driving would increase safety (Williams, 2003).

As a result many experts and individual drivers prefer to focus on reducing the small percentage of high risk driving by other motorists, rather than vehicle travel in general, or their own vehicle travel in particular. They favor “targeted” campaigns that discourage specific risky behaviors or reduce driving by particularly high-risk groups. Efforts to reduce overall mileage for safety sake may strike them as surrender to failure and confusing because it contradicts their existing safety messages.

Although these arguments are partially justified, they are overall wrong. It is true that specific risk factors such as alcohol impairment or drivers with poor driving records contribute to approximately half of all casualty crashes,¹ but that leaves about half of all crashes caused by sober, average-risk drivers making normal errors. 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. If half of all casualty crashes are caused by average-risk driving, and half the victims of crashes caused by high risk driving are occupants of other vehicles, then three-quarter of all road casualties can be avoided by reducing average-risk vehicle travel.

This is not to suggest that targeted programs are misguided. However, to the degree that they are successful and reduce higher risk driving, the portion of crashes caused by lower-risk driver will increase, and so will the safety value of mobility management.

Mobility management is seldom implemented primarily for the sake of traffic safety, its objectives are usually congestion reduction, road and parking cost savings, energy conservation and emission reductions, or improved mobility options for non-drivers. However, recognizing safety benefits can increase support for mobility management, and therefore significantly expand its implementation.

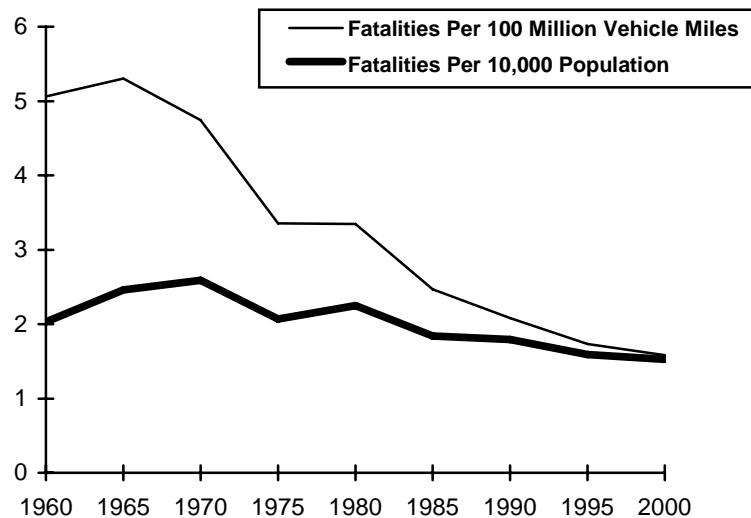
¹ According to National Highway Traffic Safety Administration’s *Traffic Safety Facts 2006*, alcohol contributed to 42% of crashes and speeding to 31% (many crashes involved both).

Evaluating Risk

Safety evaluation is affected by how crash risk is measured. Different types of data can give very different conclusions about the nature of traffic risk and how safety can be improved. Traffic safety studies measure *crashes* (also called *incidents*, *accidents* or *collisions*), *injuries*, *fatalities* and *casualties* (both injuries and fatalities). Crash statistics definitions may vary between jurisdictions, such as which types of injuries and deaths are included. Crash statistics may reflect either *reported* crashes or estimated *total crashes* (reported crashes increased by some value to include estimated unreported crashes). Casualty statistics for a particular mode may include only users of that mode or they may include other road users. Casualty rates for some modes (such as automobile and rail) are affected by whether or not suicides are included (presumably, many of these would choose another way to die if that transport mode were unavailable).

The units used to measure risk can affect analysis. For example, *crash* rates tend to increase with urban densities because interactions between vehicles become more frequent, but crash *severity* and therefore *casualties* (injuries and deaths) tend to be higher in rural areas because crashes tend to occur at higher speeds. Similarly, risk analysis can be affected by the reference units (the units used in the denominator) used in analysis, whether it is distance-based (such as per 100 million vehicle-miles or billion vehicle-kilometers), per vehicle or per capita. For example, Figure 1 illustrates traffic fatality rates using two different denominators. When measured per unit of travel, as traffic safety experts often do, 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)

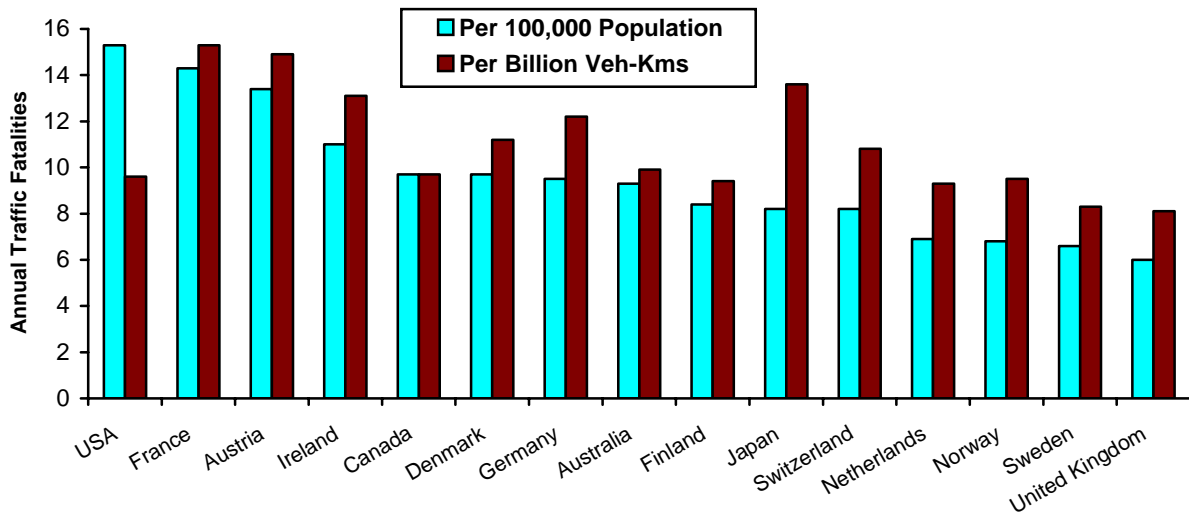


This figure illustrates traffic fatality trends over four decades. When measured per vehicle-mile, they declined significantly, but when measured per capita they show relatively little decline due to increased per capita vehicle mileage during this period.

But per capita vehicle mileage more than doubled in the U.S. over that time period, 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 are 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 about 45%), yet, per capita traffic deaths declined only about 25%.

Traffic crashes continue to be one of the greatest single causes 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.

The distinction between distance-based and per capita traffic risk analysis has particular important for the issues being analyzed in this report. Distance-based analysis treats mobility (the amount that people travel) as exogenous, outside the scope of policy interventions. When road risk is evaluated using distance-based units, 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; in fact, 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).

Comprehensive safety analysis should account for both *internal* risk (borne directly by the person imposing the risk) and *external* risk (borne by others in society). For example, increasing vehicle weight reduces occupants' risk but increases risk to other road users. Many safety strategies (seat belts and airbags) reduce a vehicle occupants' risk but not the risk to other road users. Strategies that reduced vehicle mileage or speed, or increase driver caution, reduce crash frequency and therefore both internal and external risks.

Traffic safety analysis is complicated by the tendency of risks to maintain equilibrium, that is, when accident damages are considered excessive, individuals and society react with additional safety strategies until the risk reaches a more acceptable level, called *offsetting behavior* or *target risk* (Wilde, 1994). This occurs in various ways, for example, through the implementation of safety programs targeting geographic areas, demographic groups, or travel modes that are considered high risk, therefore bringing them down to an acceptable risk level, and because individual motorists may become more cautious under more hazardous driving conditions, or after somebody they know is killed in a crash. Conversely, motorists tend to take small additional risks when they feel relatively safe, such as driving faster and talking on the telephone while driving under "normal" conditions, and deferring the replacement of worn tires until winter when driving conditions become more hazardous. Similarly, motorists who feel safer due to increased crash protection tend to drive more *intensely*, meaning that they choose higher speeds, leave less distance between their vehicles and other objects along the roadway, and in other ways take additional risks. As a result, it can be difficult to ascertain the safety impacts of a particular strategy or program.

Michael Sorensen and Marjan Mosslemi (2009) make a distinction between *objective* (actual) and *subjective* (perceived) risks. For example, of 125 traffic safety strategies they evaluated, 78 were found to have positive effects on both subjective and objective safety, 25 have conflicting effects (improves objective safety but reduces perceived safety), and 20 have uncertain effects.

In addition to crashes, transportation policy affects two other major health risks: exposure to pollution emissions, and physical fitness (Frumkin, Frank and Jackson, 2004; Litman, 2003). Reductions in per capita vehicle travel tend to reduce total pollution emissions, although more compact development patterns may increase emission density (the amount of pollution emitted per acre), and therefore increase exposure to certain harmful emissions, such as carbon monoxide. Improved walking and cycling conditions, more mixed land use (so destinations such as shops and schools are within walking distance of homes and worksites), and increased public transit use (since most transit trips involve walking or cycling links) tend to increase per capita walking and cycling activity, leading to improved physical fitness and health.

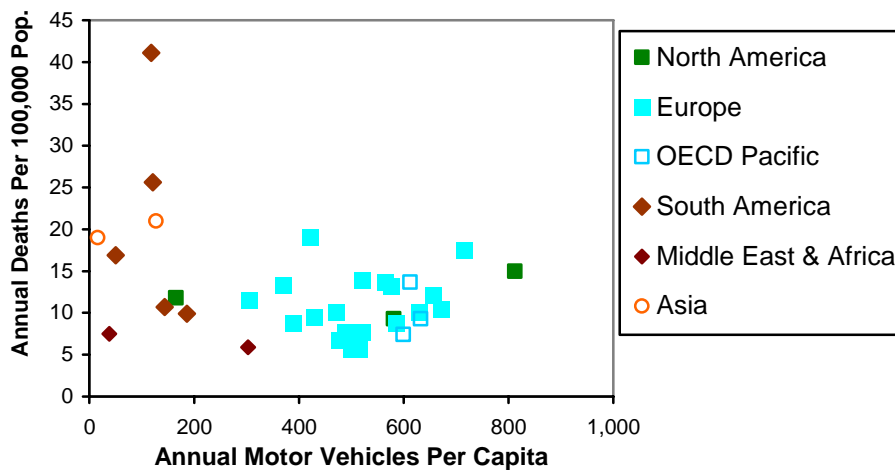
Relationships Between Vehicle Mobility And Crash Risk

To evaluate mobility management safety impacts it is important to understand the relationships between mobility (the amount and modes of travel) and crash risk. Per capita crash risk can be considered the product of two factors: per-mile crash rates times annual mileage. Changing either factor affects total crashes. Although many factors affect per-mile crash rates, these generally change little when individual motorists reduce 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 contribute to crashes by being a target on the roadway when other motorists make errors or by risks beyond their control, such as animals in the roadway or mechanical failures.

Crash casualty rates vary significantly due to demographic, geographic and transport policy factors. Per capita traffic fatality rates typically range from about 2 to 20 annual deaths per 100,000 population, a 0.15% to 1.5% lifetime risk for an average person. Each fatality is estimated to represent 15 severe injuries requiring hospital treatment, 70 minor injuries, and about 150 property damage only (PDO) traffic crashes, so typical lifetime crash injury rates range from 2% to 22% (WHO 2004).

Because so many factors influence traffic risk it can be difficult to isolate the effects of a particular factor such as per capita mileage. Less developed countries tend to have high per capita traffic fatality rates, despite low levels of motorization, and these crash rates generally decline with economic development (Kopits and Cropper 2003). Figure 3 shows the relationship between vehicle ownership and traffic fatality rates. Many low-income countries with low vehicle ownership rates have high traffic fatality rates, while wealthier countries with high vehicle ownership have low traffic fatality rates. This suggests that increased per capita vehicle travel is not a risk factor, in fact, it suggests that increased driving reduces crash risk.

Figure 3 Per Capita Vehicle Ownership and Fatalities (WHO 2004)



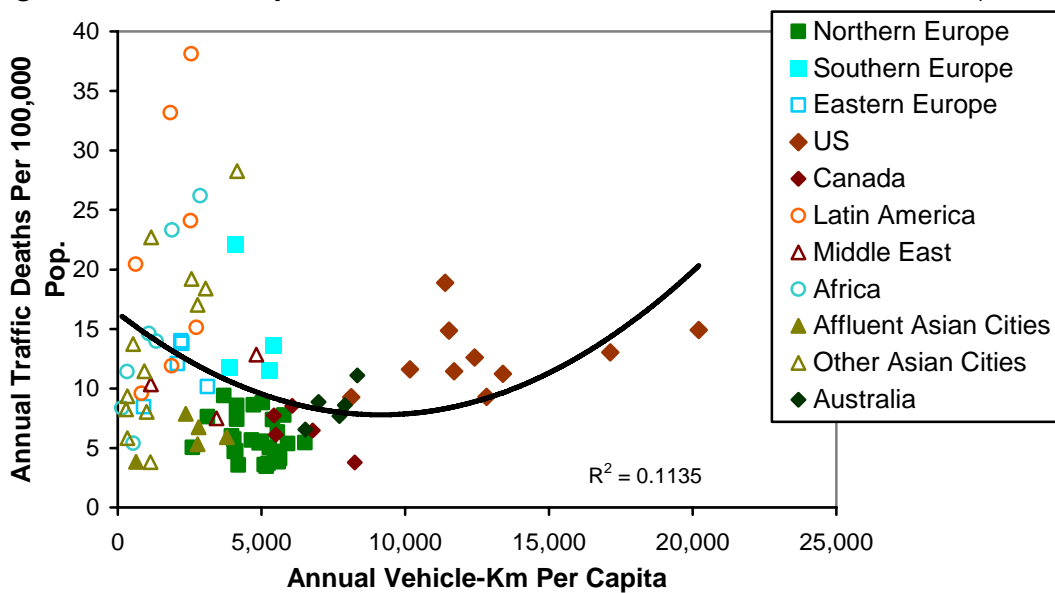
Overall, crash rates tend to decline with increased vehicle ownership.

However, these trends probably reflect other factors associated with wealth. As countries become wealthier the quality of driver training, vehicles, roadway facilities, traffic management, law enforcement, emergency response and medical care also tend to increase. Although increased vehicle ownership *is associated* with reduced crash rates, it does not cause such reductions.

There is considerable evidence indicates that for a particular area or group with similar risk profiles there is a positive relationship between per capita vehicle mileage and crash rates (Vickrey 1968; Roberts and Crombie 1995; Edlin 1998; Balkin and Ord 2001; Edlin and Karaca-Mandic 2002 and 2006; Clark and Cushing 2004; Frumkin, Frank and Jackson 2004).

Figure 4 shows the relationship between per capita vehicle travel and traffic fatalities in various cities. It is U-shaped: crash rates decline up to about 10,000 annual kilometers after which they begin to increase. The lowest fatality rates occur in higher income, lower-annual-kilometer cities in Northern Europe and Asia.

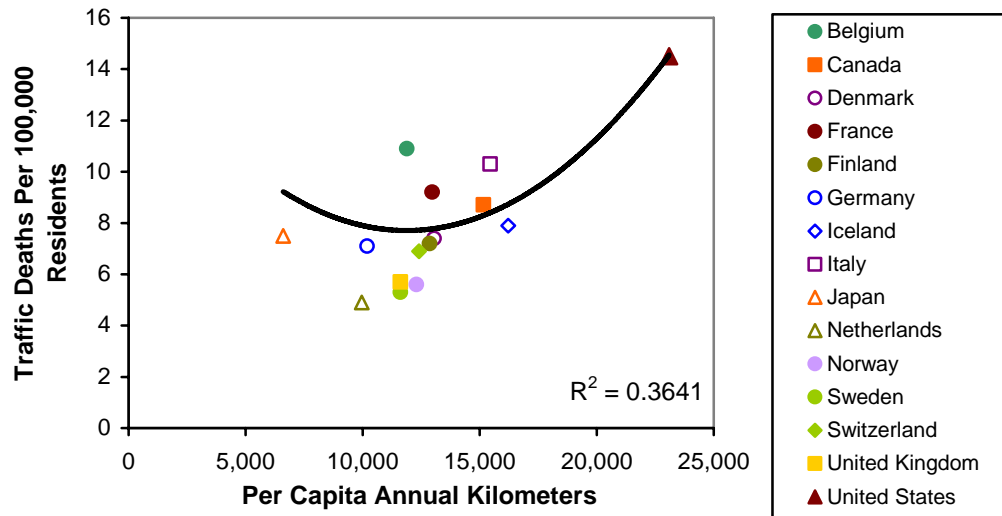
Figure 4 Per Capita Vehicle Travel and Fatalities In Various Cities (UITP, 2000)



Overall, per capita traffic fatality rates have a U-shaped relationship to per capita vehicle mileage, declining until about 10,000 annual kilometers after which they tend to increase.

Figure 5 illustrates a similar U-shaped relationship between per capita annual mileage and crashes among higher-income countries. This suggests that increases from low to moderate per capita annual vehicle travel causes relatively modest risk, but increases from moderate to high vehicle travel impose greater risk. The trend line has an R-squared value of 0.364 indicating that per capita mileage has a moderate effect on per capita crash rates.

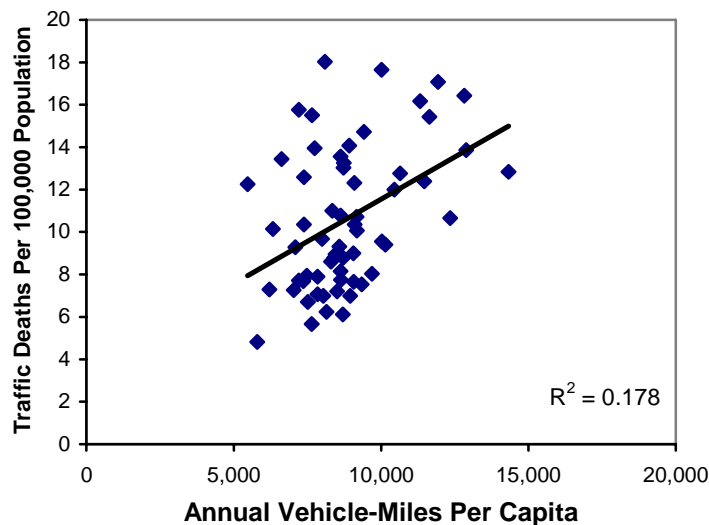
Figure 5 Vehicle Mileage and Traffic Fatality Rates In OECD Countries (OECD 2006)



Among wealthier countries there is a positive relationship between mileage and traffic fatality rates.

Figure 6 illustrates a moderate positive relationship between per capita vehicle mileage and traffic fatality rates (including pedestrian and transit deaths) for major U.S. cities.

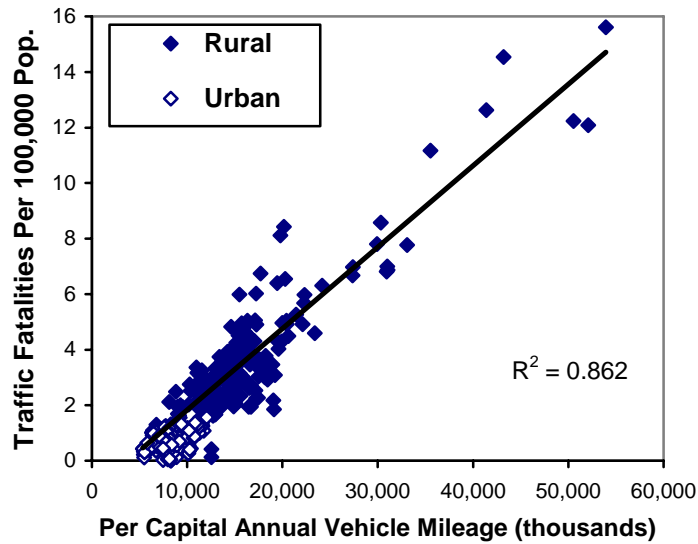
Figure 6 Vehicle Mileage and Traffic Fatality Rates For U.S. Cities (FHWA 2002)



This graph shows a moderate positive relationship between per capita annual vehicle mileage and traffic fatalities in U.S. cities.

Figures 7 through 10 show the relationship between per capita mileage and traffic fatality rates for the urban and rural areas of each U.S. state over a seven year period using FHWA data, which are considered relatively reliable and consistent. Figure 6 shows urban and rural areas together. A linear model applied to this data has an R-Squared value of 0.862, indicating a strong relationship between variables.

Figure 7 U.S. Traffic Fatality and Mileage Rates (FHWA 1993-2002 data)



This graph indicates a strong positive relationship between per capita annual vehicle mileage and traffic fatalities in U.S. states, particularly in rural areas.

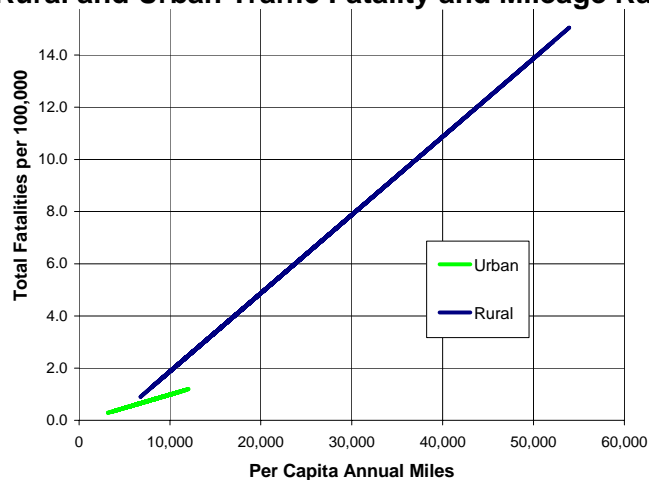
Urban and rural relationships can be calculated separately using the following equations.

$$\text{Rural Traffic Fatalities} = -1.123 + 0.0002998 * \text{Rural Vehicle Mileage} \quad (2)$$

$$\text{Urban Traffic Fatalities} = -0.03465 + 0.0001022 * \text{Urban Vehicle Mileage} \quad (3)$$

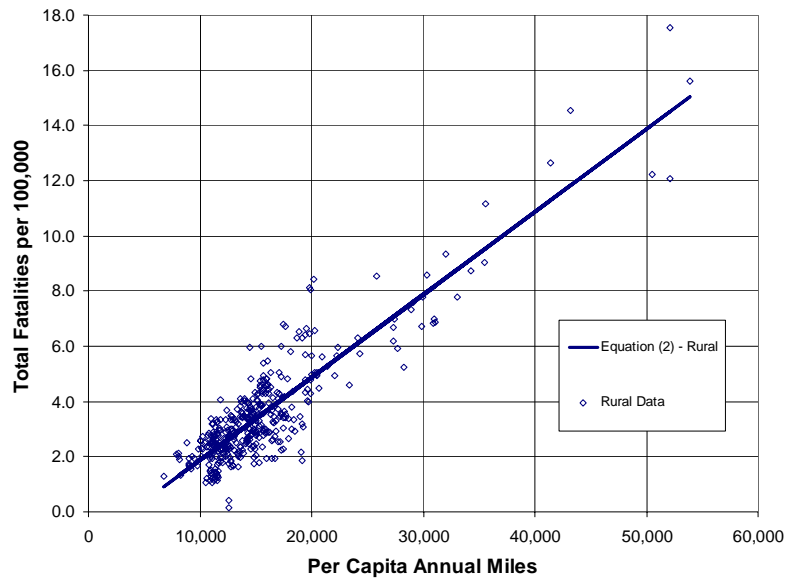
Figure 8 illustrates these equations. The rural area slope is about three times steeper than for urban areas, indicating that mileage has a stronger effect on fatalities in rural conditions, probably due to factors such as increased traffic speeds and emergency response time, less seatbelt and helmet use, and more higher-risk driving (such as young and elderly drivers) due to fewer transport alternatives (Rakauskas and Ward, 2007).

Figure 8 Rural and Urban Traffic Fatality and Mileage Rates (FHWA 1995-2002 data)



This graph shows the regression lines for urban and rural areas calculated separately.

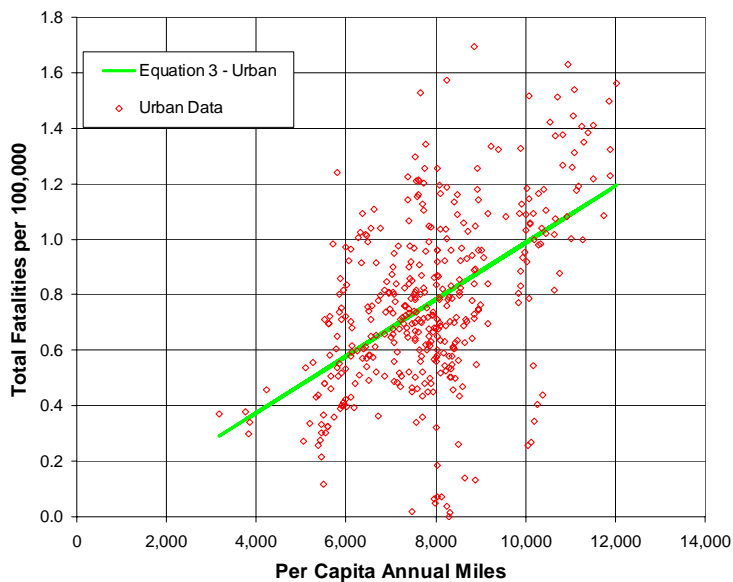
Figure 9 Rural Traffic Fatality and Mileage Rates (FHWA 1995-2002 data)



This graph shows a strong relationship between annual mileage and crash rates in rural areas ($R^2=0.80$).

Figure 9 shows the equation associating rural fatalities and mileage. Although most rural areas average less than 25,000 annual miles per capita, the few areas with very high annual mileage also have very high fatality rates. Figure 10 shows data for the urban portion of each state. The equation's shallow slope likely reflects the tendency of increased urban mileage to increase traffic congestion, which increases collision frequency but reduces collision severity and therefore fatalities (Zhou and Sisipiku, 1997; Shefer and Rietvald, 1997).

Figure 10 Urban Traffic Fatality and Mileage Rates (FHWA 1995-2002 data)

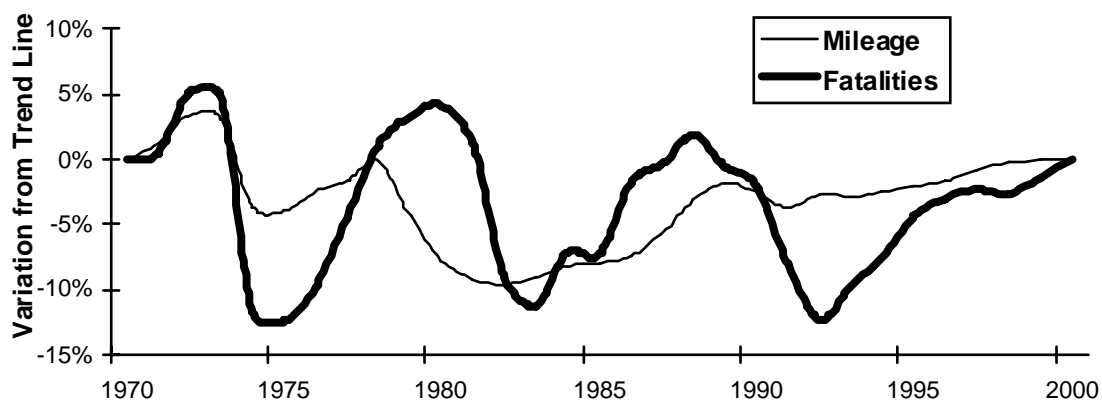


This graph shows a weaker relationship between annual mileage and crash rates in urban areas.

There are other indications of positive relationships between mileage and crash rates. Sivak (2008 and 2009) found that a 2.7% decline in U.S. vehicle travel caused by fuel price increases and a weak economy during 2007-08 resulted in a much larger 17.9% to 22.1% month-to-month declines in traffic fatalities. These results can be explained by the disproportionate reductions in vehicle travel by lower income drivers (who tend to be young and old, and therefore higher than average risk), proportionately large reductions in rural and leisure travel (which tend to have higher fatality rates than urban and commute vehicle travel), and speed reductions to save fuel.

In 2008, vehicle travel declined about 3.4% and traffic fatalities about 10% compared with previous years (Copeland, 2009). Chu and Nunn (1976) estimated that during the 1994 fuel price spike, California traffic fatalities declined 25% due to a combination of reduced vehicle travel (29%), slower traffic speeds (39%), and daylight saving time (8%). Grabowski and Morrissey (2004) estimate that each 10% fuel price increase reduces total automobile deaths by 2.3%, with about twice as large an impact on younger drivers, who tend to be more sensitive to fuel prices. At the neighborhood level, Lovegrove and Sayed (2006) found a positive relationship between total vehicle traffic and crashes.

Figure 11 Vehicle Mileage and Crash Fatality Variation (FHWA Data)



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.

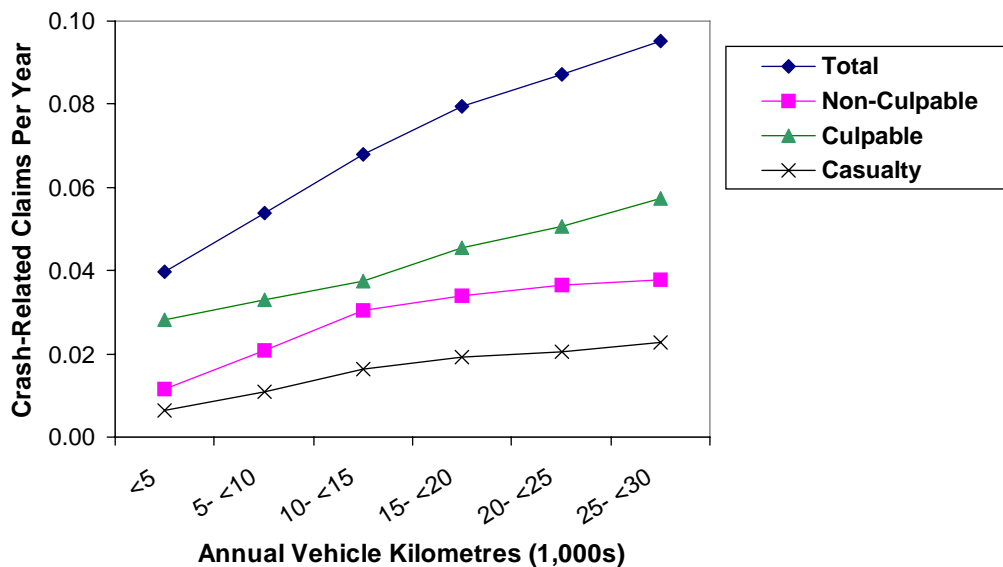
Balkin and Ord (2001) found seasonal highway fatality cycles, with annual peaks during holiday seasons when VMT increases. Reductions in annual mileage during economic recessions due to reduced employment and incomes often reduce per capita crash rates. For example, a recession in 1981-82 caused a 10% reduction in vehicle travel and a 12% reduction in insurance claims in British Columbia (ICBC data). 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). As Figure 11 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.

Elderly drivers tend to have high per-mile crash rates but low vehicle-year crash rates due to low annual mileage. Female drivers' lower crash rates are approximately equal to their lower average mileage (Butler, 1996).

The analysis described so far indicates the relationships between mileage and crash rates for a large number of vehicles in aggregate. Other types of analysis investigate the relationships between mileage and crash risk for individual drivers or vehicles. 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). Insurance industry representatives sometimes argue that mileage is a relatively minor risk factor (Cardoso and Woll, 1993), but until recently the industry lacked reliable vehicle travel data (their analysis was based on motorists' self-reported predictions of their future mileage which are extremely unreliable). More recent research based on more reliable vehicle-travel data shows a strong positive relationship between annual mileage and annual crash risk for a particular driver or vehicle (that is, holding constant other risk factors such as driver history, vehicle type and location).

Figure 12 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 that annual claims increase with increased annual mileage. Similar relationships were found when these data were disaggregated by 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 12 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.)

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 at high annual mileages, as indicated in Figure 12. 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.

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 crashes caused by another vehicle, and reducing multi-vehicle crash reduces multiple claims (Vickrey 1968; Edlin and Karaca-Mandic 2002 and 2006). 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, divides the crashes you could experience into four categories labeled A-D, depending on whether or not you are culpable and whether the crash involves single- or multiple-vehicles. We assume you are an “average” driver, so you or mechanical problems with your vehicle, cause about half the crashes you are involved in.

Table 4 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 you are involved in are caused by other motorists' mistakes, and those 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' errors (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 through D. Table 5 summarizes these impacts.

Table 5 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 (Dougher and Hogarty 1994; Clark and Cushing 2004; Ong 2004). Maze, *et al* (2005) found that rural highway crash rates per million vehicle miles increase with roadway traffic volumes, particularly at intersections.

Various factors may partly offset this additional risk from increased traffic density. First, drivers may be more cautious in denser traffic. Second, density increases congestion, which reduces speed and therefore crash severity, which explains why urban areas tend to have low fatality rates (Zhou and Sisipiku 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 the elasticity of claim costs with respect to mileage is between 1.42 and 1.85, meaning a 10% reduction in vehicle mileage reduces total crash costs 14% to 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 each 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 and declines to about 1.0 in rural areas, all else being equal. Of course, these impacts are affected by the type of mileage reduced. A strategy that reduces average risk miles by 10% should reduce total crash costs about 17% (a 10% risk reduction to motorists who reduce mileage plus a 7% risk reduction to other 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. It is wrong to assume that safety benefits only result from reductions in relatively high-risk driving. Motorists considered low risk (i.e., they qualify 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 by reducing their exposure to crashes caused by other road users’ errors.

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

1. Many mobility management strategies target urban commuting, which tends to have high crash but low fatality rates due to high traffic densities. For example, a transit use incentive program is likely to reduce crashes and insurance claims proportionately more than fatalities.
2. Some mobility management strategies affect vehicle travel by higher-risk drivers. For example, a transport management program that improves travel options for high school students or seniors may reduce mileage by higher-risk drivers.
3. Improved travel options may shift public attitudes, making it easier for courts to revoke driving privileges of higher-risk drivers.
4. Traffic management strategies, such as traffic calming and new urbanist roadway design, reduce traffic speeds and therefore crash frequency and severity.
5. Smart growth land use strategies increase land use density, which tends to increase crash frequency but reduces crash severity.

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

Various transportation price reforms are advocated to achieve various objectives, including road and parking congestion reduction, emission reductions, and increased fairness (Litman, 2005a; “Market Reforms,” VTPI, 2004). These reforms can cause various 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.

Analysis by Lovegrove and Litman (2008) using a community-based macro-level collision prediction model applied to Vancouver British Columbia area urban neighborhoods suggest that a typical congestion pricing program is likely to reduce neighbourhood collision frequency by approximately 19% (total) and 21% (severe).

Fuel Price Increases

Fuel price increases can be justified as a way to finance 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%.

Sivak (2008) found that a 2.7% decline in vehicle travel caused by fuel price increases and a weak economy during 2007-08 resulted in much larger 17.9% to 22.1% month-to-month traffic fatality reductions, probably due to disproportionate reductions in vehicle travel by lower income drivers (who tend to be young and old, and therefore higher than average risk) and speed reductions to save fuel.

Chu and Nunn (1976) estimate that during the 1974 oil crisis, when fuel prices spiked, California traffic fatalities declined 25% from what would be expected. Their model predicts that under normal conditions the state would have had 2,303 fatalities during the first half of 1974 but only experienced 1,726. They estimate that reduced travel accounted for 29%, slower driving speed for 39%, and permanent daylight saving time for 8% of the 577 total fatality reduction estimated to have occurred. Grabowski and Morrissey (2004) estimate that each 10% fuel price increase reduces total traffic deaths 2.3%, with a 6% decline for drivers aged 15 to 17 and a 3.2% decline for ages 18 to 21 according to analysis. In follow-up research, Grabowski and Morrissey (2006) estimate that each 10% gasoline tax increase is associated with a 0.6% decrease in the traffic fatality rate.

Schuffham and Langley (2002) analyzed New Zealand traffic fatality rates, taking into account vehicle travel (automobile and motorcycle ownership and mileage), economic activity (GDP) and behaviour (seatbelt use, alcohol drinking). They found that per capita crash fatalities have declined overall, likely due to safety strategies such as seatbelts and improved emergency response, but within this trend, per capita crash rates varied with changes in per capita vehicle mileage, with crash reductions when fuel price increases reduced per capita vehicle travel. Leigh and Geraghty (2008) estimate that a sustained 20% gasoline price increase would reduce approximately 2,000 traffic crash deaths (about 5% of the total), plus about 600 air pollution deaths.

There is debate concerning the safety impacts of more fuel efficient vehicles. Occupants of lighter vehicles face greater risk in crashes with heavier vehicles or stationary objects, but this seems to be offset by their 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, 2005b).

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; Edlin 1998). 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 mileage of affected vehicles by 10-12%, while higher risk motorists would pay significantly more and so are expected to reduce their mileage more than average. If fully implemented in an area, this should reduce traffic crashes by 12-15%.

There is some 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.

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 2005a). 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 shifts from automobile to alternative modes, by making alternative modes more attractive or by increasing the cost of automobile use. The safety impacts of such shifts are discussed below.

Table 6 User Fatality Rate By Mode (DfT 2003)

	Total Deaths	Miles*	Deaths Per Bil. Miles	Trips*	Deaths Per Bil. Trips	Hours*	Deaths 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	6.0	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

(* = Annual Per Capita) This table compares traffic fatality rates for various modes, using mileage, trips and hours as denominators. This only indicates risk to users, not to others.

Traffic risks varies by mode and how risk is measured, as indicated in Table 6. For example, compared with driving, the fatality rate of walking is about ten times higher *per mile*, but only about a 40% higher rate *per hour* of travel, and about equal *per trip*. If the choice is between driving or walking to a particular destination, driving is generally safer, but if the choice is between driving fifteen minutes to a shopping center or walking to a local store, the user risks are similar.

Table 7 U.S. Transportation Fatalities, 2001²

	Fatalities			Veh. Travel	Occupancy	Pass. Travel	Fatality Rate	
	User	Others	Totals	Billion Miles		Billion 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	-

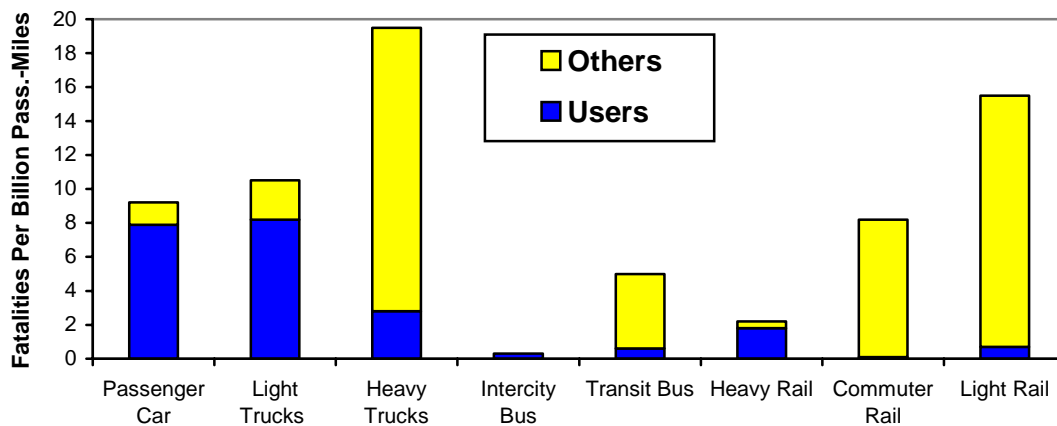
This table indicates traffic fatality rates per billion miles of travel for various modes.

² Based on BTS, *National Transportation Statistics* (www.bts.dot.gov), 2003, Tables 1-32, 2-1 and 2-4; APTA, *Safety Summary By Mode* (www.apta.com), 2003. Pedestrian and cycling mileage is based on FHWA, *National Bicycling and Walking Study Ten Year Status Report*, (www.fhwa.dot.gov), 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.

Table 6 only reflects deaths to the mode user. Comprehensive safety analysis must also consider risks imposed on others. Table 7 indicates risk to both *user* and *others* (other road users). 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.

Figure 13 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. Parry (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 100% of the crash costs in a two-vehicle crash, and up to 50% in a three vehicle crash). Applying this approach would significantly increase the allocation crash fatalities to passenger cars.

Figure 13 Transport Fatalities (FHWA and APTA Data 2002)



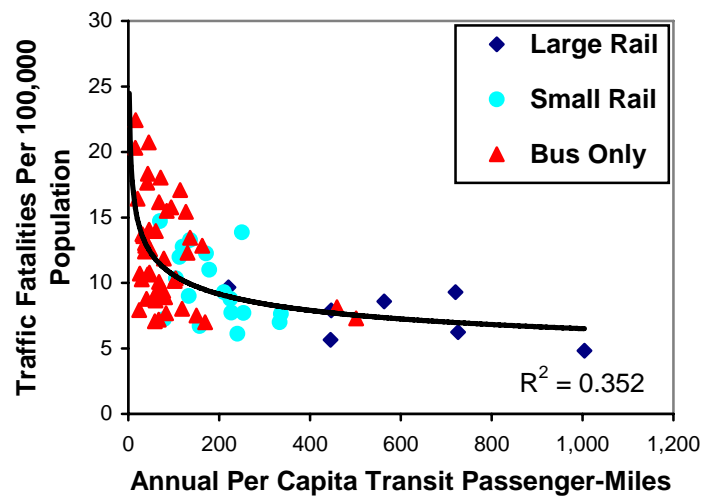
Transit travel tends to have lower crash rates than automobile travel, even taking into account risks to other road users.

Analysis by Lovegrove and Litman (2008) using a community-based, macro-level collision prediction models suggests that improving transportation options (better walking and cycling conditions, and improved ridesharing and public transit services) could reduce collision frequency by 14% (total) and 15% (severe)

Transit

Public transit is a relatively safe mode, particularly for users, as indicated in Figure 14.³ 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. 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 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. Mobility management strategies that encourage transit ridership and increase average transit vehicle occupancy impose little incremental external risk and reduce crash rates per passenger-mile.

Figure 14 U.S. Traffic Deaths (Litman 2004)

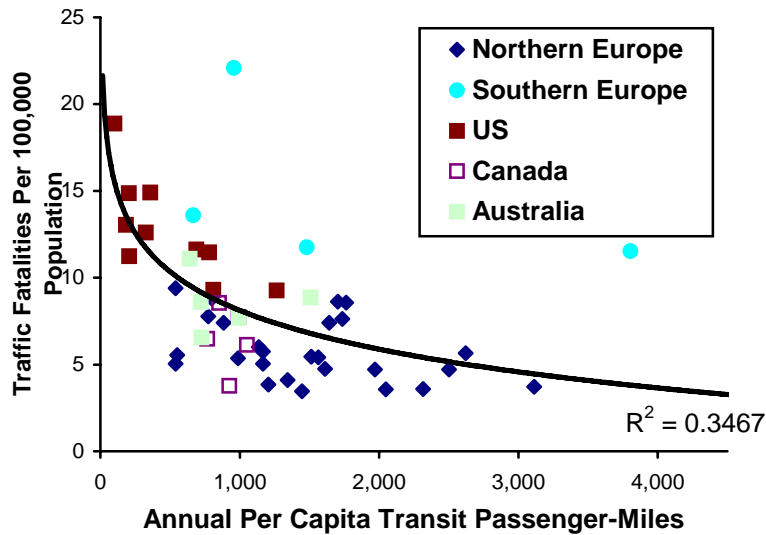


Per capita traffic fatalities (including automobile occupants, transit occupants and pedestrians) tend to decline with increased transit ridership.

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 15. International data also indicate per capita traffic deaths decline with increased transit ridership, as indicated in Figure 13. Table 8 indicates very low fatality and injury rates for transit passengers in the UK. Lim, et al (2006) describes how Bus Rapid Transit improvements in Seoul, South Korea increased transit ridership more than 20%, but reduced bus casualties by 11% and total traffic crashes by 26%. Multiple regression analysis found that bus accident rates were influenced by factors such as the extent of bus driving experience, driver wages, number of repair personnel, vehicle age, and the ratio of bus exclusive lanes to the length of total bus routes.

³ 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 15 Traffic Fatalities Vs. Transit Travel (Kenworthy and Laube 2000)



International data indicate that crash rates decline with increased transit ridership.

Table 8 UK Crash Rates Per Billion Pass-Kms (Steer Davies Gleave 2005, Table 7.3)

Mode	Killed	Killed and Injured
Motorcycle	112	5,549
Cycling	33	4,525
Walking	48	2,335
Private car	3	337
Bus or Coach	0.1	196
Heavy Rail	0.1	13
Light Rail	0.00002	0.00007

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 2004). 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 total vehicle mileage which should reduce total vehicle crashes, but this will be partly offset by increased injuries per crash. People who rideshare rather than drive alone bear about the same level of internal risk but reduce risk to others by reducing traffic volumes. For example, if increased ridesharing caused average vehicle occupancy to increase 10% and mileage to decline 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%. Ridesharing may increase safety if drivers are more cautious when they have passengers, or if they rely on the most skilled driver or safest vehicle in the group. However, some HOV lanes have relatively high crash rates (Cothron, et al, 2005), and loaded vans may have a relatively high rollover rate which may increase risk under some conditions (NHTSA, 2001).

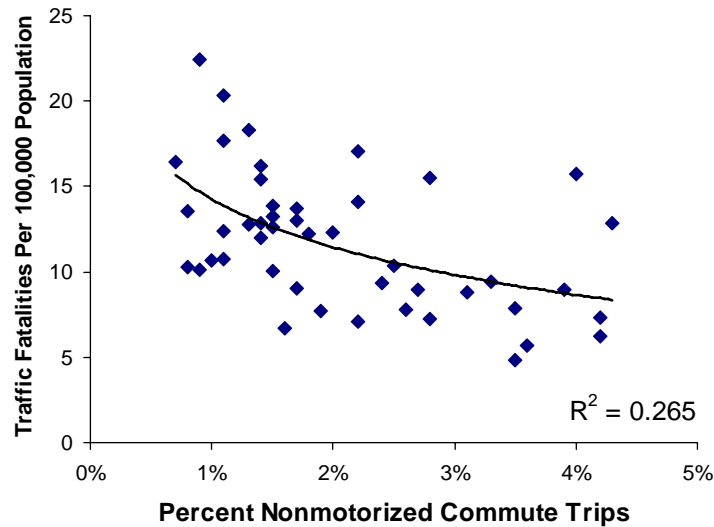
Nonmotorized Transport

Walking and cycling tend to have higher user crash rates per-mile than motorized modes, as indicated in Table 8. But mobility management strategies that increase nonmotorized do not necessarily increase total risk because (WHO 2008a):

1. Nonmotorized travel imposes minimal risk to other road users.
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. Drivers tend to be more cautious in areas where they expect to encounter walkers and cyclists.
4. Increased walking and cycling may stimulate nonmotorized travel improvements.
5. 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.
6. Some walking and cycling promotion programs include education and facility improvements that reduce per-mile bicycle crash rates.
7. Walking and cycling provide health benefits, including physical fitness and air pollution emission reductions, that may offset increased accident risks.

Chu (2003 and 2006) concludes that walking has 1.7 times the fatality rate per minute of travel than motor vehicle travel, with significant variation by time of day, age of walker and how risk is measured. Death rates range from 1 pedestrian fatality per 10 million walking hours during early afternoon up to 400 deaths per 10 million hours late at night, and are particularly high for older pedestrians. Walking and driving fatality rates per minute are both higher in the U.S. than in European Union countries (Pucher and Dijkstra, 2000). 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.

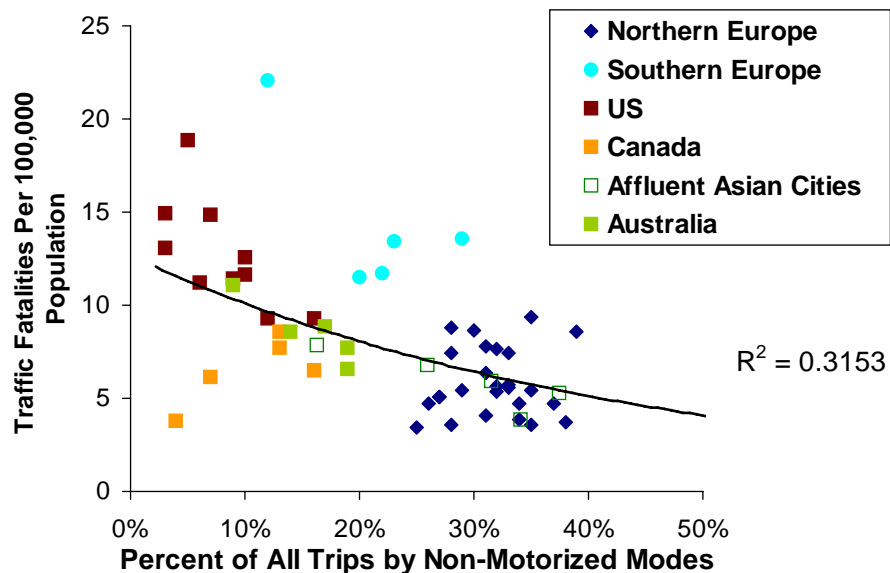
Figure 15 Traffic Fatalities Vs. Non-Motorized Transport (US Census 2000)



Per capita traffic fatality rates tend to decline as nonmotorized travel increases in a city. This equation has a low R-square (0.265), but the estimate coefficients are significant.

As nonmotorized travel increases in a community, both total per capita traffic casualty rates and per-mile pedestrian and cyclist crash rates tend to decline, as indicated in figures 15 and 16, an effect sometimes called *safety in numbers*. Economically developed countries with high rates of nonmotorized travel, such as Germany and the Netherlands, have pedestrian fatality rates per billion kilometers walked a tenth as high, and bicyclist fatalities rates only a quarter as high, as in the United States (Pucher and Dijkstra 2000; Fietsberaad 2008).

Figure 16 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 various 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. Wittink (2003), Jacobsen (2003), Robinson (2005), Geyer, Raford and Ragland (2006), and Turner, Roozenburg and Francis (2006) also find that shifts from driving to nonmotorized modes by sober, responsible adults are unlikely to significantly increase total accidents, and that per capita collisions between motorists and nonmotorized road users decline as nonmotorized transport activity increases.

Jacobsen 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 motorist declines 34% if walking and cycling double in a community). Robinson (2005) found similar results using Australian data: doubling bicycle travel reduces cyclist risk per kilometer by about 34%; and conversely, halving bicycle travel increases risk per kilometer about 52%. Modeling by Elvik (2009) indicates that shifting travel from motor vehicles to walking or cycling can reduce total traffic accidents.

The *Health Economic Assessment Tool for Cycling* (HEAT for Cycling) is a World Health Organization computer program that estimates the economic savings resulting from reduced mortality due to cycling. Lindsay, Woodward and Macmillan (2008) used the HEAT model to estimate the effects on air pollution and health of replacing light vehicles with bicycles for varying proportions of short trips (≤ 7 km) for adults in urban settings in New Zealand. They conclude that total health benefits significantly outweigh incremental road crash costs. Due to *safety in numbers* effects, the benefit/cost ratio increases as bicycle mode split increases (the ratio is 3:1 for 1% substitution and over 30:1 for 20% substitution). Shifting 5% of vehicle km to cycling would be consistent with the goal for walking and cycling in the New Zealand Transport Strategy (30% of urban trips by 2040), and would return cycling to 1980 levels. This would save about 22 million litres of fuel annually and reduce about 0.35% of transport-related greenhouse emissions. The health effects would include 116 deaths avoided annually as a result of increased physical activity, 5.6 fewer deaths due to local air pollution from vehicle emissions, and an additional 5 cyclist fatalities from road crashes. In economic terms, the health effects would amount to net savings of approximately \$193 million per year.

The San Francisco Department of Public Health developed an Vehicle-Pedestrian Injury Collision Model which predicts how demographic, geographic and land use planning factors affect the number of collisions resulting in pedestrian injury or death in an area (SFDPH 2008). The model indicates that pedestrian injuries and deaths increase with motor vehicle traffic volume, vehicle traffic speeds, pedestrian volume, and various intersection and street design factors.

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 illnesses than 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. 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 to less congested 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

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). One major study concluded that speeding is a major road safety problem in many countries, and reducing average speeds on the roads by only 5% would reduce fatalities approximately 20% (OECD/ECMT 2006).

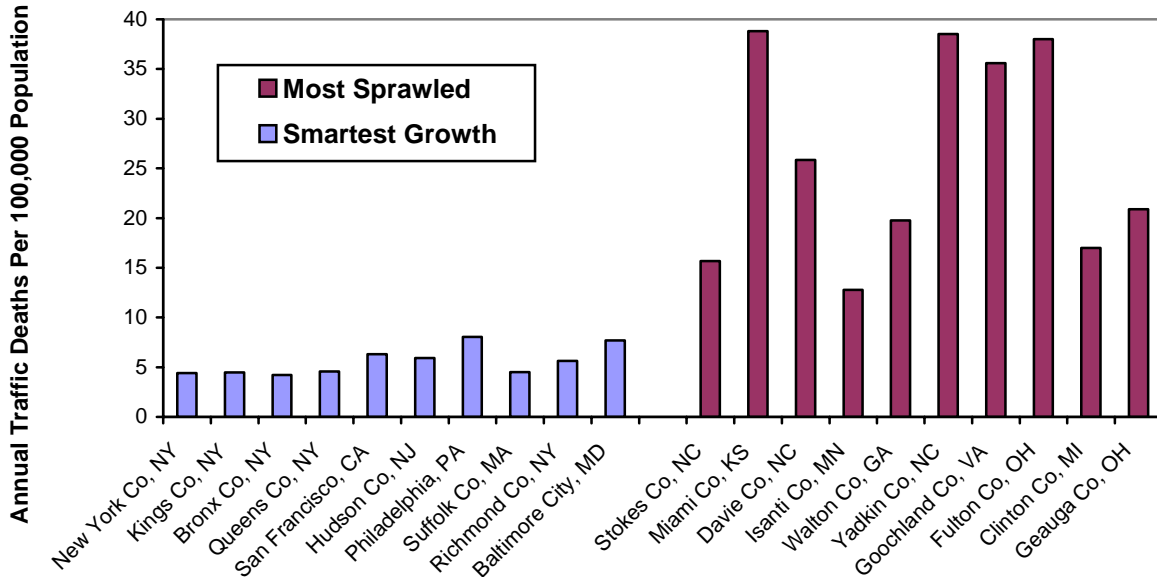
Streetscaping and Traffic Calming

Streetscaping and traffic calming include various roadway design features that control traffic speeds and volumes, accommodate alternative modes (sidewalks, bike lanes, high-occupant vehicle lanes, etc.) and improve roadway aesthetics. 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%). A detailed review by MacDonald, Sanders and Supawanich (2008) concluded that roadside landscaping is generally found to improve highway safety, but the literature is unsettled about the danger versus benefits roadside trees pose to those driving along the roadway. They found that improving walkability tends to increase walking activity and public health.

Smart Growth Land Use Management

Smart 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*.

Figure 17 Annual Traffic Death Rate (Ewing, Schieber and Zegeer 2003)



The ten communities with the lowest sprawl rating have about a quarter of the per capita annual traffic fatality rates of the most sprawled communities.

Land use patterns have various impacts on travel and traffic crash risk (“Land Use Impacts On Transportation,” VTPI 2004). Increased density tends to increase *crash rates per vehicle-mile*, but reduces *traffic fatalities per capita*, due to less per capita mileage and less severe crashes. Ewing, Schieber and Zegeer (2003) find that per capita traffic fatality rates increase with the degree of sprawl in a community, as indicated in Figure 17. This reflects differences between regions; similar effects probably exist within regions. For example, a smart growth neighborhood is likely to have a lower traffic fatality rate than a more sprawled neighborhood within the same region. Durning (1996) found that per capita traffic casualties are about four times higher for residents of low-density suburbs than for residents of higher-density urban neighborhoods in the Puget Sound region. Ewing, Schieber and Zegeer found that each one percent increase in their index toward smart growth reduces the area’s traffic fatality rate by 1.5%. Fatality rates per pedestrian travel mile also declined with an increase in this index.

Analysis by Lovegrove and Litman (2008) using a community-based, macro-level collision prediction models suggests that a smart growth strategy of more compact, multi-modal land use development patterns can reduce per capita neighbourhood collision frequency by 20% (total) and 29% (severe).

Several factors may contribute to these safety impacts. Smart growth reduces per capita vehicle mileage, but typically only by 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 less driving by higher-risk drivers, since non-drivers have better mobility options. Conversely, in automobile dependent communities people drive more, drive faster, teenagers obtain drivers licenses and vehicles at a younger age, elderly people continue to drive, and authorities are hesitant to revoke the driving privileges (for example, when motorists with DWI convictions argue that they need to drive to work). Overall, city residents are safer, taking into account risks that increase with urban living, such as pedestrian fatalities and homicides (Durning 1996; Lucy 2002 and 2003).

A study by Garrick and Marshall (2008) investigated the relationships between connectivity, network configuration, density, severe vehicle crashes, and mode choice. They analyzed twenty-four California cities at the block level; half were classified as “safe cities” (severe/fatal crash rates one-third of the state average), and half as “less safe cities” (severe/fatal crash rates close to the state average).

Safer Cities

- 106/sq mile average intersection density.
- 16% walking/biking/transit mode share.
- 3.2 average annual traffic deaths per 100,000 population.

Less Safe Cities

- 63/sq mile average intersection density.
- 4% walking/biking/transit mode share.
- 10.5 average annual traffic deaths per 100,000 population.

The safer cities were mainly established prior to 1950, while the less safe cities are more recent. Even within cities there are large differences in safety related to street network design. For example, the pre-1940s sections of Davis, CA, (intersection density 211/sq mi) had a fatal/severe crash rate that was half the rate of the post-1970 sections of town (intersection density 111-132/sq mi). The walking/biking/transit mode share was 59% in the pre-1940 sections of town compared with 14% in the post-1980 sections. In addition to intersection density, the researchers also investigated street network configuration — grid patterns, cul-de-sac patterns, and everything in between. The results were consistent across the board, with highly connected networks of small blocks exhibiting the best performance in all categories.

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 9 summarizes the travel, safety and health impacts (pollution exposure and physical fitness) of various mobility management strategies.

Table 9 Mobility Management Safety and Health Impact Summary

Category	Travel Changes	Safety Impacts	Health Impacts
Pricing reforms (road and 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.	Some shifts to alternative modes which reduces total pollution emissions and increases physical fitness.
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.	Some shifts to alternative modes which reduces total pollution emissions and increases physical fitness.
Transit improvements, HOV priority, park & ride	Shifts automobile travel to transit	Moderate to large safety benefits. Shifts from automobile to transit reduce per-mile crash rates, and tend to reduce total automobile travel.	Reduced total pollution emissions, and tends to increase nonmotorized travel and therefore physical fitness.
Ridesharing, HOV priority	Shifts to single occupant travel to ridesharing	Moderate safety benefits. Reduces total vehicle traffic, but crashes that occur may involve more victims.	Reduces total emissions and may increase nonmotorized travel and therefore physical fitness.
Walking and cycling improvements, traffic calming	Shifts motorized travel to nonmotorized modes	Mixed safety impacts. Can increase per-mile to users, but reduces risk to others, reduces total person-miles and increases driver caution.	Can provide significant health benefits. Reduces total pollution emissions.
Telework, delivery services	Reduces total vehicle travel	Modest safety benefits. Reduced vehicle travel reduces crashes, but benefits may be partly offset by rebound effects.	Uncertain health impacts. Reduces total pollution emissions.
Flexitime, congestion pricing	Shifts travel from peak to off-peak	Mixed. Reducing congestion tends to reduce crashes, but increased speed increases crash severity.	Uncertain impacts on health and pollution emissions.
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.	Tends to improve walking and cycling conditions, providing health benefits.
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.	Reduces total pollution emissions but may increase exposure increasing density. Tends to increase nonmotorized travel and therefore fitness.
Time and location driving restrictions.	Vehicle Use Restrictions	Mixed. Provides safety benefits if total vehicle travel declines, but not if vehicle travel shifts to other times and routes.	Provides pollution reduction and fitness benefits if total vehicle travel declines and use of non-motorized travel increases.

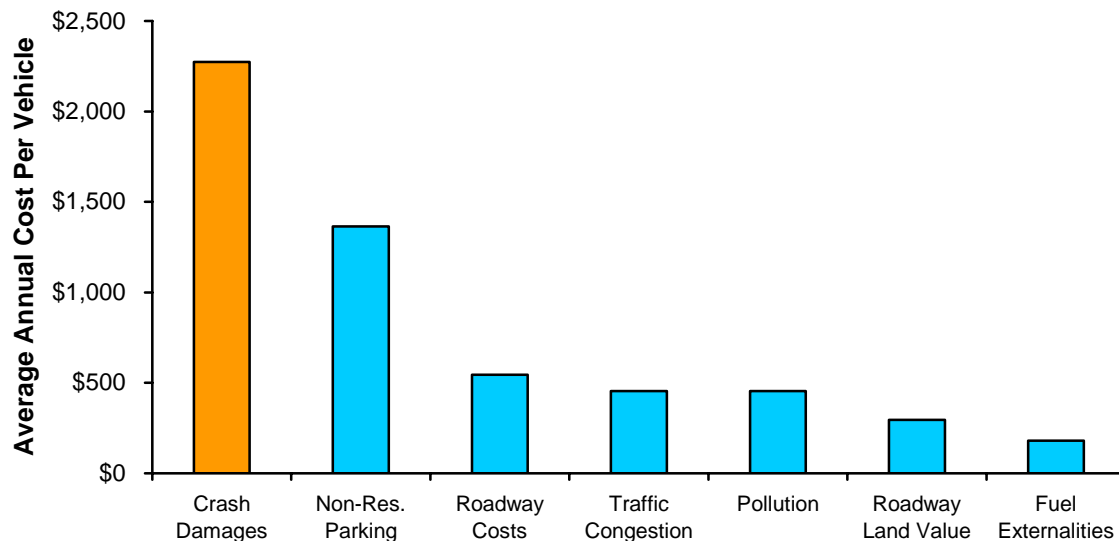
This table summarizes the safety and health impacts of various mobility management strategies.

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 2006). 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 18.⁴

Figure 18 Costs of Motor Vehicle Use in the U.S. (Litman 2006)



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

⁴ 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 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 larger (Litman 2005a).

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 $80\% \times 85\% = 68\%$, 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 arguments fail to consider several important issues.

First, 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 (“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 2005a). 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 tend 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.

Most people realize that vehicle travel is risky (although surveys indicate that most drivers consider themselves “better than average,” sometimes called the “Lake Woebegone Effect,” apparently out of pride and perhaps as a form of psychological denial of the hazards they face and impose on others). Motor vehicle use therefore consists of travel in which user benefits exceed users’ direct, perceived crash costs. Motorists would therefore not want to reduce their own vehicle mileage just for the sake of their own safety. However, reduced mileage reduces external crash costs, including uncompensated crash damages and risks imposed on other road users. These external benefits can therefore justify mobility management safety programs.

Traffic risk tends to maintain equilibrium, that is, when it is considered excessive individuals and communities take actions to reduce risks to a more acceptable level, for example, by driving more cautiously under dangerous conditions and implementing safety programs targeting higher-risk behaviors, conditions and groups. This suggests that mobility management strategies can be relatively better than engineering strategies to reduce traffic risk, such as airbags and larger vehicles that give drivers the feeling of increased security and therefore tend to encourage riskier behavior. The effects of such offsetting factors should be taken into account when evaluating the safety impacts of any safety strategies, including mobility management.

Mobility management strategies can help achieve various planning objectives, including congestion reduction, road and parking facility cost savings, consumer cost savings, improved mobility options for non-drivers, support for strategic land use objectives (such as urban redevelopment and reduced sprawl), energy conservation and emission reductions, as well as reduced crash risks. More comprehensive analysis, which takes into account more of these impacts, tends to justify more emphasis on mobility management (“Comprehensive Transport Planning,” VTPI 2004).

Transportation professionals generally focus primarily on congestion and vehicle emission impacts when evaluating decisions that affect total vehicle mileage. Safety impacts are often overlooked. As a result conventional planning tends to overlook the full costs of decisions that increase vehicle mileage (such as roadway capacity expansions and reduced vehicle user fees), and undervalues the full benefits of mobility management strategies 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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