

5.3 Safety and Health Impacts

This chapter examines transportation safety and health impacts, including crash damages, personal security and public health. It describes how these impacts are measured, how they vary by mode and travel conditions, and how they are distributed. It summarizes crash cost and health benefit estimates.

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5.3.2 Definitions

Crash costs

Crash costs refer to the economic value of damages (also called *losses*) caused by vehicle *crashes* (also called *collisions*, *accidents* or *incidents*). Injuries and fatalities together are called *casualties*. *Severity* refers to the degree of damage caused by a crash. *Vulnerable road users* refers to pedestrians, cyclists and motorcyclists. *Road risk* is a general term for road traffic crash costs. *Road safety* refers to a reduction in road risk. *Health Costs* refers to the economic value of both injuries and disease.

Crash costs include *internal costs*, which are damages and risks to the individual traveling by a particular vehicle or mode, and *external costs*, which are uncompensated damages and risks imposed by an individual on other people. Table 5.3.2-1 lists major crash cost categories, including market and non-market costs.

Table 5.3.2-1 Categories of Crash Costs

Market	Non-Market
<ul style="list-style-type: none"> • Property damages to vehicles and other objects. • Lost income. • Emergency response services. • Medical treatment costs. • Crash prevention and protection expenditures. 	<ul style="list-style-type: none"> • Crash victim’s pain and suffering. • Crash victim’s lost quality of life. • Uncompensated grief and lost companionship to crash victims’ family and friends. • Reduced nonmotorized travel due to crash danger.

This table summarizes major categories of crash costs.

Some safety experts prefer the term “crash” to “accident,” because *accident* implies a random event while *crash* emphasizes they have a cause that could be avoided. On the other hand, the term *accident* recognizes that all travel incurs risk. Most travelers take small risks, such as looking away from the road to adjust a radio or driving slightly faster than is safe, without crashing. Crashes typically result if several risk factors occur together, for example, a driver being distracted when another vehicle makes a turn under poor visibility conditions. Crashes can therefore be considered to have a cause (or multiple causes), and still be random.

Crash cost analysis involves two steps. First, *quantify* physical impacts, such as the number of crashes that occur, the number and severity of vehicle damages, human injuries, disabilities and deaths. Second, *monetize* (measure in monetary values) these impacts. It is relatively easy to monetize market costs, such as vehicle damages, medical expenses and disability compensation. Various techniques, described in Chapter 4 and below, are used to monetize non-market impacts such as pain and reduced quality of life.

Active Transportation Health Benefits

Health costs due to inactivity can, like crash costs, be divided into internal costs borne by the individual and external costs born by others. The health benefits of active transportation are also divided into internal benefits to the individual and external benefits which accrue to others. For example, a person who becomes healthier and

therefore enjoys life more and lives longer free of disabling disease enjoys obvious *internal benefits*; however, the individual’s employer will likely also benefit from higher productivity which is an *external benefit*.

Physical Activity refers to physical exercise, which has a major effect on health. Cardiovascular diseases are the leading causes of premature death and disability in developed countries, causing ten times as many lost years of productive life as road crashes.¹ Even modest reductions in these illnesses can provide large health benefits.

Many experts believe that *active transportation* (walking, cycling and their variations) is the most practical and effective way for most people to maintain a healthy level of physical activity.

Discussion

Transport decisions can affect human safety and health in several ways described below.

5.3.3 Crashes

Traffic crashes are fairly rare events when considered per year or mile, as indicated in the table below. The average motorist has: less than one culpable (at fault) vehicle insurance claim each decade, and these are mostly minor claims involving property damage only; one culpable crash-related claim every 24 years; and one causality crash (with an injury or death) just once every 62 year. Even high-risk motorists (such as young males) drive most years without a culpable crash. However, some minor crashes not reported to insurance companies so insurance statistics underreport minor crashes.

Table 5.3.3-1 Vehicle Insurance Claim Frequencies in British Columbia (1997)²

	Total	Non-culpable	Culpable	Casualty
Annual Chance of an Insurance Claim	15%	6%	9%	3%
Years/Claim	7	16	11	29
Kms/Claim	131,686	323,242	222,215	580,641
Annual Chance of Police-Reported Crash	7%	3%	4%	2%
Years/Crash	14	35	24	62
Kms/Crash	282,319	692,989	476,401	1,244,820

Most vehicles are driven many years without being involved in a reported crash.

However, over a lifetime crashes are common occurrences and when serious crashes occur the damages can be catastrophic. Each year traffic crashes cause tens of thousands of deaths, millions of injuries and billions in financial losses. Traffic crashes are a leading cause of death among people in the prime of life.³ The table below summarizes U.S. transport fatality data for various modes.

¹ Christopher Murray Ed. (1996), *Global Burden of Disease and Injury*, Center for Population and Development Studies, Harvard University School of Public Health (www.hsph.harvard.edu).

² Insurance Corporation of British Columbia (1998) (www.icbc.com).

³ Christopher Murray Ed. (1996), *Global Burden of Disease and Injury*, Center for Population and Development Studies, Harvard University School of Public Health (www.hsph.harvard.edu).

Table 5.3.3-2 U.S. Transportation Fatalities (1999)⁴

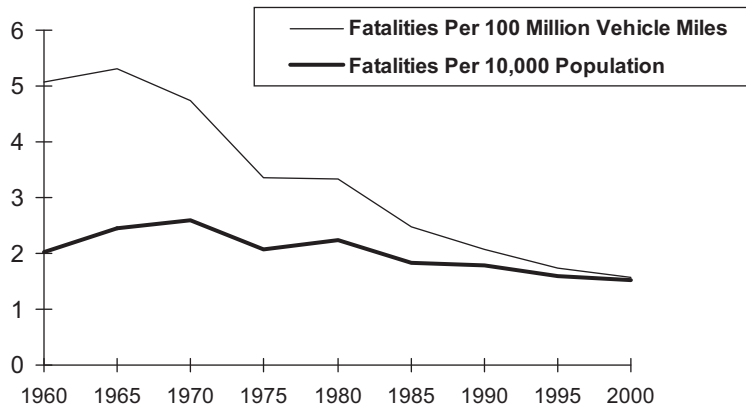
	Deaths	Billion Veh. Miles	Deaths Per Billion Veh. Miles	Average Occupancy	Deaths Per Bil. Pass. Miles
Passenger Car Occupants	20,818	1,550	13.4	1.59	8.4
Motorcycle Passengers	2,472	10	242.4	1.1	220
Truck Occupants	12,001	1,064	11.3	1.52	7.4
School & Transit Bus Occ.	58	7.4	7.8	10.7	0.7
Intercity Bus Occupants	0				0.2
Commercial Air Travel	0				0.3
Transit Bus – Total	91	2.3	39.6	10.7	3.7
Commuter Rail – Total	95	0.265	358.5	36.0	10.0
Subway – Total	84	0.566	148.4	23.0	6.5
Light Rail Transit – Total	17	0.043	395.3	25.2	15.7
Pedestrians	4,906				
Cyclists	750				
Total	41,292				

Occ. = Occupants. Total = Includes vehicle occupants of other road users.

Crash Evaluation Perspectives

How crashes are measured affects how risks are evaluated. For example, traffic fatalities per vehicle-mile have declined substantially during the last several decades, suggesting a substantial safety improvement, but this was largely offset by increased vehicle-mileage, resulting in little reduction in per capita fatalities, as indicated in the figure below.

Figure 5.3.3-1 U.S. Motor Vehicle Crash Rate⁵



Crash fatality rates have declined significantly per vehicle mile, but not much per capita.

Similarly, comparisons depends on the perspective and unit used for analysis, such as whether it considers internal (user), external or total risk, and whether risk is measured

⁴ BTS (2001), *National Transportation Statistics*, Bureau of Transportation Statistics, USDOT (www.bts.gov/publications/nts), Tables 2-1 and 2-4

⁵ BTS, *National Transportation Statistics*, Bureau of Transport Statistics (www.bts.gov), annual reports.

per vehicle-mile, passenger-mile, trip or hour of exposure.⁶ Table 5.3.3-3 below indicates that non-motorized modes have relatively high crash rates per unit of travel, but the additional risk is smaller when measured per-trip or per-hour. Shorter nonmotorized trips often substitute for longer automobile trips (for example, people often choose between walking to a local store and driving to a more distant supermarket). Drivers tend to travel about three times as many miles as non-drivers.

Table 5.3.3-3 Fatalities per 100 Million Passengers in Britain (1992)⁷

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

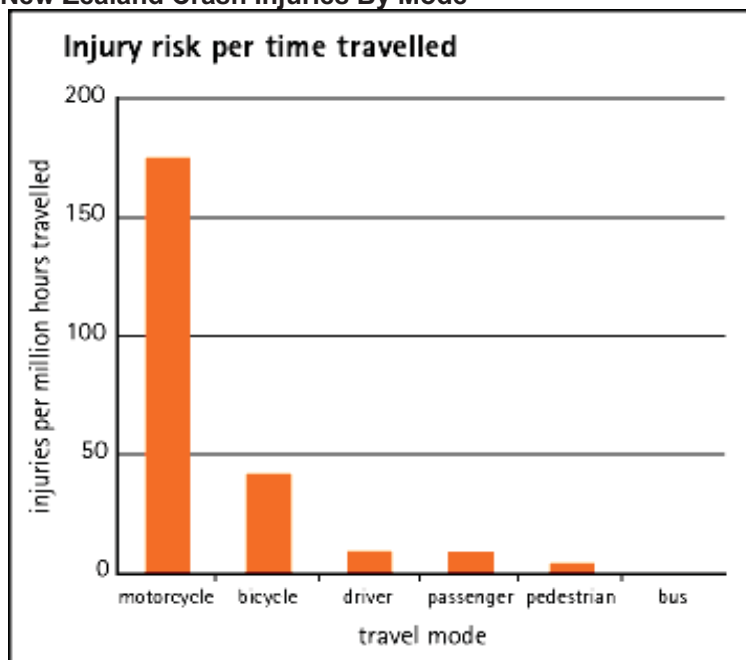
Faster modes have low crash rates per mile, but not so low when measured per trip or hour.

The New Zealand Ministry of Transportation calculates crash injury rates per unit of travel time, as indicated in the figure below. Measured this way, motorcycle travel has the highest risk, followed by cycling, automobile travel, pedestrian travel and public transit.

⁶ Todd Litman and Steven Fitzroy (2005), *Safe Travels: Evaluating Mobility Management Traffic Safety Benefits*, Victoria Transport Policy Institute (www.vtpi.org); updated version at www.vtpi.org/safetrav.pdf

⁷ Royal Society for Prevention of Crashes (1997), “Fasten Your Safety Belts,” *The Economist* (www.economist.com), 11 Jan. 1997, p. 57.

Figure 5.3.3-2 New Zealand Crash Injuries By Mode⁸



This figure illustrates crash injury rates per unit of time for various travel modes.

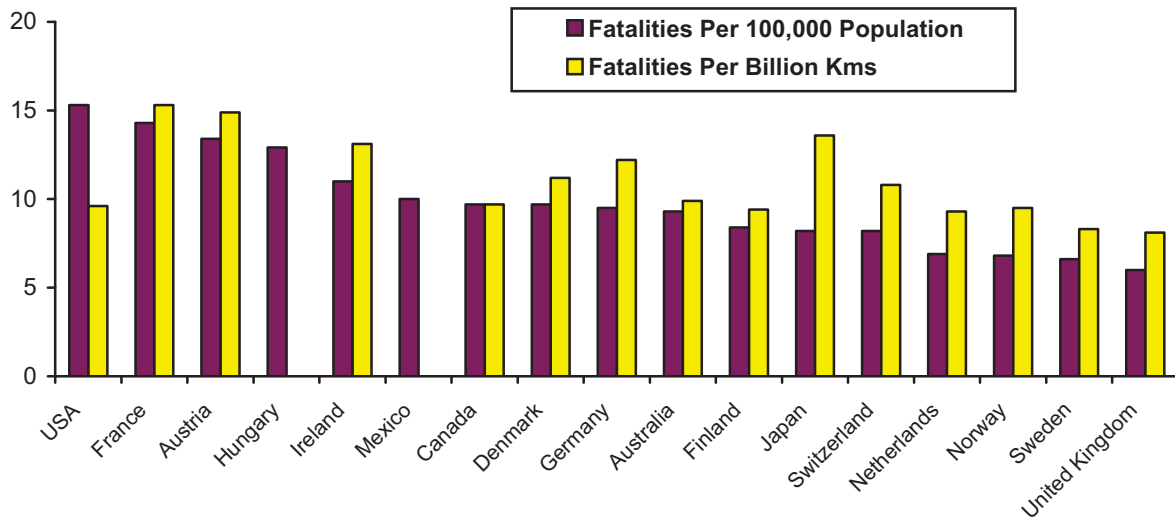
Data used to evaluate transport risks vary between jurisdictions, times and modes. For example, some data sets only include deaths that occur at a crash site, others include deaths within a certain number of days or months. Some transit and rail fatality data include suicides, and even passenger assaults and illnesses that occur on a transit vehicle or train stations. Traffic accident statistics generally include only unintentional injuries and deaths, but it is often difficult to identify suicides, which exaggerates fatality rates. On the other hand, some traffic deaths are not recorded in official statistics for various reasons. For example, if an accident victim dies several months later or commits suicide due to injury-related depression, these are usually not counted as motor vehicle deaths.

Annual traffic fatality rates in various jurisdictions typically range from about 2 to 20 annual deaths per 100,000 population, a 0.15% to 1.5% lifetime risk for an average individual. 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 the lifetime chance of a traffic crash injury typically ranges from 2.25% to 22.5%.⁹

⁸ NZMT (2006), *Risks of Different Modes*, New Zealand Ministry of Transport (www.transport.govt.nz); at www.transport.govt.nz/risk-modes.

⁹ WHO (2004), *World Report on Road Traffic Injury Prevention: Special Report for World Health Day on Road Safety*, World Health Organization (www.who.int), April 2004, p. 5; at www.who.int/world-health-day/previous/2004/en/

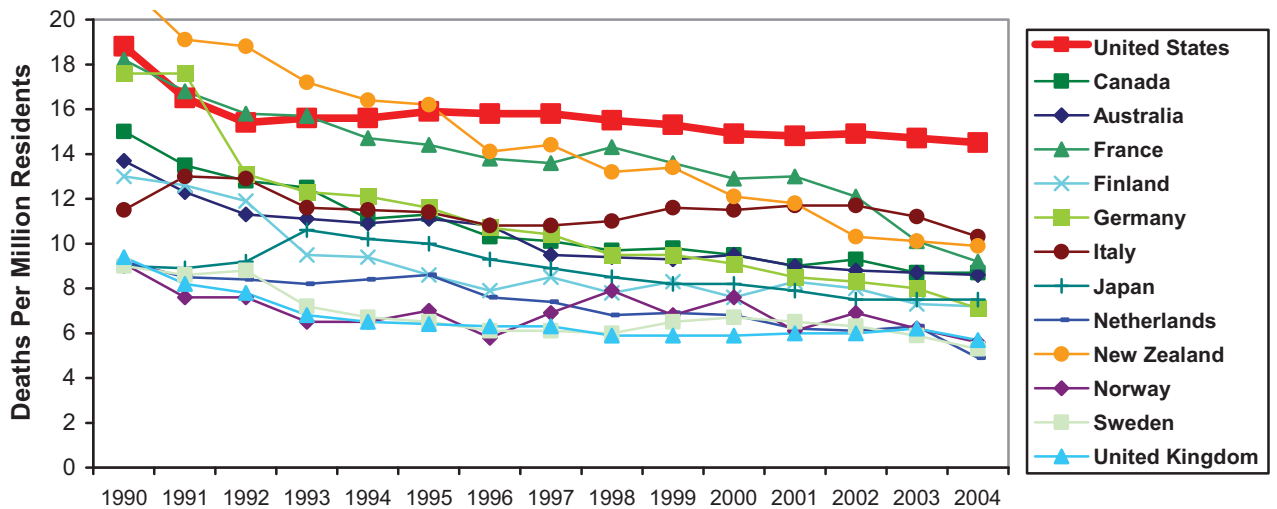
Figure 5.3.3-3 International Traffic Fatality Rates¹⁰



The U.S. has one of the lowest per-mile and one of the highest per-capita crash rates.

The United States has one of the lowest per-mile traffic fatality rates, and one of the highest per capita traffic fatality rates, of all countries in the world, due to high annual per capita vehicle travel, as indicated in Figures 5.3.3-4.

Figure 5.3.3-4 Traffic Fatalities Per Million Residents in OECD Countries, 1990-2004.¹¹



This table shows traffic fatality trends in various OECD countries from 1990-2004.

¹⁰ OECD (March 2001), *International Road Traffic and Accident Database*, Organization for Economic Cooperation and Development (www.oecd.org).

¹¹ OECD (2006), *Factbook 2006: Economic, Environmental and Social Statistics*, Organization for Economic Cooperation and Development (www.oecd.org).

Risk Equilibrium

Traffic safety analysis is also complicated by the tendency of risk to maintain equilibrium. When risk is considered excessive, individuals and society react with additional safety strategies until it is reduced to a more acceptable level, called *offsetting behavior* or *target risk*.¹² This occurs in various ways, for example, through implementation of safety programs targeting areas, groups or 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 drive more *intensely* (take small additional risks, such as driving faster, leaving less shy distance, and talking on a telephone) if they feel relatively safe, due to vehicle safety features (seat belts, air bags, etc.), and predictable driving conditions. Empirical research indicates that *this offsets about a third of the safety gain, and increases risks to vulnerable road users*.¹³ As a result, it can be difficult to ascertain the safety impacts of a particular strategy or program.

Monetizing Crash Impacts

Several analytic techniques are used to monetize human health risks, as described in Chapter 4. Human life is not a commodity: most people place infinite value on their own life (they would not willingly die for any amount of money), but many decisions involve tradeoffs between marginal changes in risk and market goods. For example, vehicle purchasers must sometimes decide whether to pay extra for safety equipment such as air bags for a small increase in safety. Such tradeoffs indicate the value consumers place on marginal changes in risk, described as *willingness-to-pay* or *willingness-to-accept*. For example, if consumers pay an average of \$100 for optional safety equipment that reduces their chances of crash injury by one millionth, then other strategies that provide equal safety benefits for the same financial investment can be considered cost effective.

The proper conceptual framework for determining fair and efficient compensation for damages that resulted from a crash caused by another driver is willingness-to-accept, that is, the amount of financial compensation that a particular victim requires before he or she would volunteer to experience such damages. This reflects the assumption that individuals have a right to live without being injured by others.¹⁴ Willingness-to-pay tends to result in lower values than willingness-to-accept due to budget constraints. For

¹² Gerald Wilde (2004) *Target Risk*, PDE Publications, Toronto; at <http://psyc.queensu.ca/target>

¹³ Robert Chirinko and Edward Harper, Jr. (1993), "Buckle Up or Slow Down? New Estimates of Offsetting Behavior and their Implications for Automobile Safety Regulation," *Journal of Policy Analysis and Management*, Vol. 12, No. 2 (www.appam.org/publications/index.asp), pp. 270-296.

¹⁴ The difference between willingness-to-pay and willingness-to-accept reflects the allocation of "rights." If road users have no inherent right to safety, they would be obliged to pay other drivers to avoid crashing into them, so willingness-to-pay is the appropriate test for crash cost valuation. If road users are considered to have a right to safety, then the appropriate test is willingness-to-accept for crash damages. Standard legal and economic practice assume that individuals have a fundamental right to be safe from damages caused by other people's actions, indicating that willingness-to-accept is the appropriate measurement technique for crash damage compensation analysis.

example, consumers may value increased safety but cannot afford to pay for it, so willingness-to-pay values are low, yet they would be unwilling to accept reduced safety in exchange for a financial reward, so their willingness-to-accept values are relatively high.

Society's willingness-to-pay to avoid crash damages tends to be greater than what is reflected by simply summing crash compensation or vehicle insurance payments, since many crash damages (particularly for nonmarket damages such as pain, suffering and lost-quality of life) are not fully compensated. For example, if a person with no dependents dies in a crash, minimal financial compensation may be paid. Similarly, injuries to drivers considered legally responsible for a crash (such as a drunk driver) are often uncompensated, yet society still considers these lives to have value and devotes resources to preventing such crashes and reducing such injuries. Many jurisdictions have injury claim limitations, and various types of no-fault insurance systems which effectively limit crash claim payments below what the legal system would otherwise deem fair compensation, in order to make vehicle insurance more affordable.¹⁵

Rather than just measuring human deaths, some studies evaluate risks based on Potential Years of Life Lost (PYLL) or Disability Adjusted Life Years (DALYs), which account for age differences in when people are harmed. Vehicle crashes tend to injure people at a younger age than other common health risks such as heart disease and cancer (the average age of death from motor vehicle crash is 39 years, compared with 71 for all causes), and so impose a relatively high cost per death or disability.¹⁶

Two general perspectives are used in crash cost studies, reflecting the scope of impacts that are considered:¹⁷

- The *Human Capital* method measures only market costs (property damage, medical treatment, and lost productivity). This typically places the value of saving a human life at \$0.5-1 million, with lesser values for injuries.
- The *Comprehensive* approach adds non-market costs, including pain, grief, and reduced quality of life, as reflected by people's willingness-to-pay for increased safety (i.e., reduced risk of crashes and reduced crash damages), or willingness-to-accept increased crash risk and damages. It is a more appropriate measure of the true cost to society of crashes, and the appropriate value to use when assessing crash prevention.

¹⁵ Public policies that tend to undercompensate full crash costs may be justified, in part, as an incentive for individuals to take safety precautions that reduce risk from other drivers mistakes, and to discourage people who place a relatively low value on their own health from intentionally causing crashes as a way to obtain financial compensation. This is one situation in which efficiency and equity objectives conflict: full compensation is fair, but may encourage risky behavior.

¹⁶ Henri Richardson (1997), *Motor Vehicle Traffic Crashes as a Leading Cause of Death in the U.S.*, National Highway Traffic Safety Administration, USDOT (www.nhtsa.dot.gov), DOT HS 808 552.

¹⁷ Ted Miller (1991), *The Costs of Highway Crashes*, FHWA (www.fhwa.dot.gov), Publ. No. FHWA-RD-055.

There is some variability in these cost values since analysis results depend on how research is conducted and the economic and demographic attributes of the population under consideration (for example, values are generally considered higher for people in the prime of life than for people who are older and so can expect to live fewer years). Blincoe, et al. state that the value of a fatality lies in the range of \$2-7 million, and assign a “working value” of \$3,366,388¹⁸. This suggests that a reasonable range is from about 40% lower to about 200% higher than their assigned values, at least for crashes involving significant non-market (quality of life) damages.

Crash Cost Distribution

How crash costs are distributed is an important issue for some types of analysis. Individual actions and public policies sometimes shift crash costs from one group to another. For example, motorists who purchase larger vehicles may increase their own safety, but increase risks to other road users. Public policies may reduce compensation provided to crash victims, which reduces insurance costs but increases uncompensated damages borne by individuals. It is important to track these economic transfers.

Crash costs can be divided into *internal* (damages borne by the individual who uses a particular vehicle), *external* (damages and risks borne by other road users), and insurance compensation (damages compensated by insurance). Insurance compensation costs are external at the individual level but internal to premium payers as a group. The table below indicates how various categories of crash costs are distributed.

Table 5.3.3-4 Crash Cost Categories

Distribution	Market	Non-Market
Internal	Safety equipment expenditures. Uncompensated property damages, lost income and medical treatment costs to users. Insurance deductibles.	Uncompensated pain and lost quality of life to crash victims.
External	Uncompensated property damages, lost income and medical costs to nonusers. Emergency response and crash prevention expenditures.	Uncompensated pain and lost quality of life borne by nonusers. Uncompensated grief to victims’ loved ones. Reduced nonmotorized mobility.
Insurance	Property damage, lost income and medical treatment compensated by insurers.	Pain, grief and lost quality of life compensated by insurers.

This table indicates how various crash costs are categorized. Some are market, others are non-market. Some are internal, others external. Insurance compensation costs are external to individuals, but internal to motorists as a group.

When crashes involve different vehicle types, such as pedestrians hit by automobiles or automobiles hit by trains, it is common to consider the larger vehicle responsible for most

¹⁸ Lawrence Blincoe, et al. (2002), *Economic Cost of Motor Vehicle Crashes 2000*, USDOT, Report Number DOT HS 809 446. NHTSA (www.nhtsa.gov); at <http://lhsc.lsu.edu/OutsideLinks/EconomicImpact-1.pdf>

crash costs, since it imposes greater damages, regardless of which driver is legally responsible. Elvik defines three types of crash externalities:¹⁹

- *System externalities*: crash damage costs impose on society: property damages, emergency and medical services, lost productivity, etc.
- *Physical injury externalities*: costs larger vehicles impose on smaller vehicles and pedestrians.
- *Traffic volume externalities*: marginal changes in crash risk from changes in traffic density.

He concludes that 37-44% of Norwegian crash costs are external, including 29% system externalities and 15-24% physical externalities. Transport Concepts estimates that 3% to 47% of crash costs are external and argues that the higher range is most appropriate.²⁰ Miller estimates crash costs are distributed as shown in Figure 5.3-5. Jansson emphasizes external costs crashes imposed on “unprotected road users” (pedestrians, cyclists and motorcyclists), and damage costs borne by society.²¹ Other researchers also stress the costs motor vehicle risk impose on pedestrians and cyclists,²² which tends to be undervalued because such crashes are under-recorded,²³ and because non-drivers experience reduced mobility and security.

¹⁹ Rune Elvik (1994), “The External Costs of Traffic Injury: Definition, Estimation, and Possibilities for Internalization,” *Crash Analysis and Prevention*, Vol. 26, No. 6, pp. 719-732.

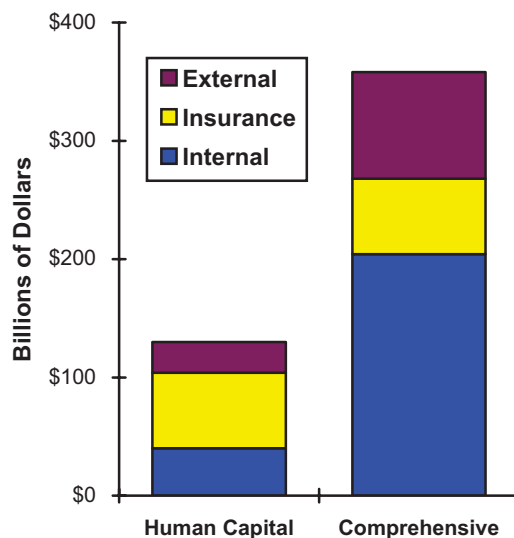
²⁰ Rune Elvik (1994), *External Costs of Truck and Train*, Transport Concepts (Ottawa), p. 12.

²¹ Jansson (1994), “Crash Externality Charges,” *Journal of Transport Economics and Policy* (www.bath.ac.uk/e-journals/jtep/), January 1994, p. 31-42.

²² Adrian Davis (1992), “Livable Streets and Perceived Crash Risk: Quality of Life Issues for Residents and Vulnerable Road Users,” *Traffic Engineering and Control* (www.tecmagazine.com), June 1992, pp. 374-387; Robert Davis (1992), *Death on the Streets*, Leading Edge (North Yorkshire).

²³ Helen James (1991), “Under-reporting of Road Traffic Crashes,” *Traffic Eng+Con* (www.tecmagazine.com), Dec. 1991, pp. 574-583.

Figure 5.3.3-4 Crash Cost Distribution²⁴



This figure compares two estimates of total crash costs. Human Capital only considers financial costs. Comprehensive analysis includes pain, grief and reduced quality of life.

An efficient market requires that individuals bear the costs they impose, so crash cost externalities should generally be evaluated at an individual level, particularly because individuals can control the risk they impose on others by how they travel, the vehicles they use, and how cautiously they drive. Insurance pricing and other risk-related fees should reflect the marginal costs imposed by each additional vehicle-mile driven, taking into account driving patterns, vehicle type and roadway conditions. Because motor vehicle use imposes various types of external crash risk and uncompensated crash damages, optimal pricing of crash risk is likely to be somewhat higher than indicated by insurance premiums.²⁵ For example, insurance premiums might average 5¢ per vehicle mile overall, but optimal pricing of crash costs might average 8¢ per mile, to internalize all marginal costs.

When non-market costs such as pain or lost quality of life are compensated by insurance or litigation, they become market costs. As mentioned earlier, such compensation rates are generally not a good indication of the full value of reducing crash damages. The more appropriate indicator of non-market crash costs is individuals' willingness-to-accept marginal changes in crash risk.

²⁴ Based on Ted R. Miller, Shelli B. Rossman & John Viner (1991) *The Cost of Highway Crashes*, Urban Institute (www.urban.org).

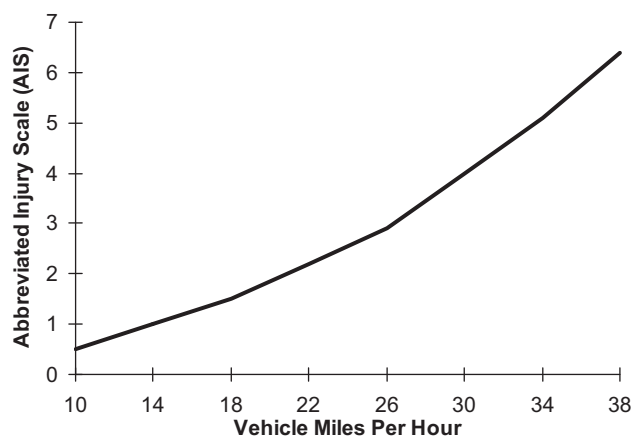
²⁵ William Vickrey (1968), "Automobile Accidents, Tort Law, Externalities, and Insurance: An Economist's Critique," *Law and Contemporary Problems*, 33, pp. 464-487, available at the VTPI website www.vtpi.org/vic_acc.pdf; VTPI (2008) "Pay-As-You-Drive Vehicle Insurance" *Online TDM Encyclopedia*, (www.vtpi.org); at www.vtpi.org/tdm/tdm79.htm

Roadway Conditions and Vehicle Speed

Many factors affect crash rates including roadway design, traffic speeds, traffic density, vehicle mix and speed variation.²⁶ There is some debate about the impact of traffic speed on crash risk. Some researchers argue that speed *variation* is a greater risk factor than speed itself. Although this may be true for the *frequency* of crashes, increased traffic speeds increases crash *severity*.²⁷ A summary of research indicates that each 1-mph change in traffic speeds causes a 5% change in crash fatalities, with greater impacts on high-speed highways where a 1-mph change can change fatality rates 8-9%.²⁸

Pedestrian injury severity increases with the square of vehicle impact speed, as indicated in Figure 5.3-6. Pedestrian death probability is 3.5% at 15 mph, 37% at 31 mph and 83% at 44 mph.²⁹

Figure 5.3.3-5 Impact Speed Versus Pedestrian Injury³⁰



The severity of pedestrian injury increases with vehicle impact speed.

²⁶ FHWA (2002), *Highway Economic Requirements System: Technical Report*, Federal Highway Administration, U.S. Department of Transportation (www.fhwa.dot.gov); available at <http://isddc.dot.gov/OLPFiles/FHWA/010945.pdf>.

²⁷ e.g. Jack Stuster and Coffman, Zail (1998), *Synthesis of Safety Research Related to Speed and Speed Limits*, FHWA-RD-98-154 Federal Highway Administration (www.fhwa.dot.gov); at www.tfhrc.gov/safety/speed/speed.htm

²⁸ D.J. Finch, P. Kompfner, C.R. Lockwood and G. Maycock (1994), *Speed, Speed Limits and Crash*, Transport Research Laboratory (Crowthorne, UK).

²⁹ Rudolph Limpert (1994), *Motor Vehicle Crash Reconstruction and Cause Analysis*, Fourth Edition, Michie Company (Charlottesville), p. 663.

³⁰ ITE (1997), *Traditional Neighborhood Development Street Design Guidelines*, Institute of Transportation Engineers (www.ite.org), p. 18.

Traffic Congestion

Crash rates tend to increase with traffic density,³¹ so urban driving tends to have more claims per vehicle-mile than rural driving, although rural crashes tend to be more severe because they occur at higher speeds.³² *Crash rates tend to be lowest on moderately congested roads (V/C=0.6), and increase at lower and higher congestion levels, while fatalities decline at high levels of congestion, indicating a trade off between congestion and safety impacts.*³³ Per mile crash rates are three times higher for urban driving, but fatality rates per mile are about twice as high for rural driving, as indicated in the table below.

Table 5.3.3-5 Vehicle Accident Rates by Road System in Iowa³⁴

Road Type	Crash Rate Per 100 Million Vehicle Miles		
	All Accident	Fatal Accident	Fatal + Injury Accident
Rural			
Interstate	57	0.45	18
Primary	133	1.97	42
Secondary	261	3.26	94
<i>Total</i>	<i>147</i>	<i>1.91</i>	<i>50</i>
Municipal			
Interstate	137	0.69	54
Primary	472	1.15	181
Secondary	558	0.79	174
<i>Total</i>	<i>469</i>	<i>0.88</i>	<i>157</i>

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

Roadway Expansions

Increased road capacity and design speeds tend to increase average traffic speeds and induce additional vehicle travel. As a result, *although road projects may reduce per-mile crash rates, the combination of higher traffic speeds and increased vehicle travel may increase per capita fatality rates.*³⁵ To the degree that roadway improvements increase traffic speeds and induce additional vehicle travel they may increase total crashes.³⁶

³¹ Mary Janke (1991), “Accidents, Mileage, and the Exaggeration of Risk,” *Accident Analysis and Prevention*, Vol. 23, No. 3 (www.elsevier.com/locate/inca/336), pp. 183-188.

³² BTS (1997), *National Transportation Statistics*, Bureau of Trans. Statistics, (www.bts.gov), Table 3-10.

³³ Min Zhou and Virginia Sisiopiku (1997), “On the Relationship Between Volume to Capacity Ratios in Accident Rates,” *Transportation Research Record 1581*, Transportation Research Board (www.trb.org), pp. 47-52; D. Shefer and P. Rietvald (1997), “Congestion and Safety on Highways: Towards an Analytical Model,” *Urban Studies*, Vol. 34, No. 4, pp. 679-692.

³⁴ Iowa Department of Transportation (1995), *Miles, Vehicle Miles, Accidents and Accident Rates in Iowa By Road System, 1989-1993*, Transportation and Engineering Division, Iowa Department of Transportation.

³⁵ Robert Noland (2001), *Traffic Fatalities And Injuries: Are Reductions The Result Of ‘Improvements’ In Highway Design Standards?* Imperial College, London, presented at the Transportation Research Board Annual Meeting, January 2001; at www.cts.cv.ic.ac.uk/staff/wp5-noland.pdf

³⁶ Gary Ginsberg, Eli Ben-Michael, Stephen Reingold, Elaine Fletcher and Elihu Richter (2003), “How Many Shall Live? Whom Many Shall Die? Deaths Resulting From the Trans-Israel Highway and Alternatives: A Risk Assessment Revisited,” *Earthscan Reader on World Transport Policy & Practice*, Earthscan (www.earthscan.co.uk), pp. 247-258.

Distance Traveled and Mobility Management

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). The study also suggest that vehicle kilometers traveled (VKT) and safety is so closely correlated that VKT can be used as a proxy for predicting the safety impacts of specific policies and programs.³⁷ Mobility management safety impacts are affected by the travel changes they cause. Although difficult to predict with precision, available information suggests the following:³⁸

1. 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 higher 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.

³⁷ Gordon Lovegrove and Todd Litman (2008), *Macrolevel Collision Prediction Models to Evaluate Road Safety Effects of Mobility Management Strategies: New Empirical Tools to Promote Sustainable Development*, TRB 87th Annual Meeting (www.trb.org); at www.vtpi.org/lovegrove_litman.pdf.

³⁸ Todd Litman and Steven Fitzroy (2008), *Safe Travels: Evaluating Mobility Management Traffic Safety Benefits*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/safetrav.pdf, p. 38.

Vehicle Type and Mode

All else being equal, occupants of lighter vehicles face greater risk in multi-vehicle crashes, although this is partly offset by vehicle design and behavior changes.³⁹ A 240-kg increase in vehicle mass reduces fatalities an average of 10%, compared with a 43% reduction from seat belt use.⁴⁰ Taking into account both internal and external crash risk, larger vehicles such as light trucks and sport utility vehicles have equal or greater overall crash costs.⁴¹ Rideshare passenger risk depends on the type of vehicle and driver, and impose virtually no additional external risk. Public transit is very safe for passengers, and has relatively low total crash costs.

Table 5.3.3-6 Risks by Transportation Modes (Safety Evaluation)

Mode	Internal Risk	External Risk	Security	Health Impacts
Average Car	Moderate.	Moderate.	“Road rage” risk	Reduces active transport
Compact Car	Higher risk if hit by larger vehicles.	Lower risk to occupants of other vehicles.	“Road rage” risk	Replaces active transport
Electric Car	Higher risk if hit by larger vehicles.	Lower risk to occupants of other vehicles.	“Road rage” risk	Replaces active transport
Large Vehicle (Van, Light Truck, SUV)	Reduced risk in multi-vehicle crashes. Higher rollover crash risk.	High.	“Road rage” risk	Replaces active transport
Rideshare Passenger	Depends on vehicle and driver.	No incremental cost.	Minimal.	May replace active transport
Transit	Very low.	Moderate.	Assault risk.	Usually involves some walking
Motorcycle	Very high.	Low risk to other road users.	“Road rage” risk	Replaces active transport
Bicycle & Walk	High per mile. Moderate per capita.	Minimal.	Assault risk.	Beneficial. Can offset incremental crash risk
Telework	Minimal	Minimal	Minimal	May replace active transport

This table compares the safety and health impacts of various travel modes.

Nonmotorized modes tend to have relatively high crash risks per mile, although this is offset by reduced risk to other road users, shorter trips (people often choose between walking to a local store and driving to a more distant shop), and reduced crash rates

³⁹ IIHS (1998), *Occupant Death Rates In Two-Vehicle Crashes, Deaths In 1990-95 Model Passenger Vehicles And Other Vehicles*, Insurance Institute for Highway Safety (www.carsafety.org).

⁴⁰ Dagmar Buzeman, David Viano and Per Lovsund (1998), “Car Occupant Safety in Frontal Crashes,” *Journal of Crash Analysis & Prevention*, Vol. 30, No. 6, pp. 713-722.

⁴¹ Marc Ross and Tom Wenzel (2001), *Losing Weight to Save Lives: A Review of the Role of Automobile Weight and Size in Traffic Fatalities*, ACEEE (www.aceee.org); Malcolm Gladwell (2004), “Big and Bad: How the S.U.V. Ran Over Automobile Safety,” *New Yorker*, January 12, pp. 28-33.

where walking and cycling activity increase.⁴² A traveler who shifts from driving to responsible walking or cycling probably reduces total crash costs, and is healthier overall due to the additional exercise.⁴³

Freight Transport

Transport Concepts estimates truck crash risk to be six times greater than train per unit of freight travel, and calculate costs per freight ton-mile at approximately \$0.50 for truck and 7.6¢ for rail.⁴⁴ Forkenbrock estimates external crash costs for heavy intercity trucks to average 0.59¢ per ton-mile.⁴⁵

Operator Factors

Various risk factors associated with the type of driver, cyclist or pedestrian that affect safety are described below.⁴⁶

- Children tend to make errors, such as walking or cycling into traffic, and so impose special crash risks.
- Young male drivers (16-25 years of age) tend to have relatively high crash rates per vehicle mile.
- Older drivers (over 70 years of age) tend to have relatively high crash rates per mile, but they tend to drive relatively low mileage, resulting in relatively low crash rates per year.
- Driving under the influence of alcohol or drugs greatly increases the chance of causing a crash.
- Driving while talking on a telephone increases the chance of causing a crash, although there has been considerable debate over the magnitude of this impact.⁴⁷

⁴² S.A. Turner, A. P. Roozenburg and T. Francis (2006), *Predicting Accident Rates for Cyclists and Pedestrians*, Land Transport New Zealand Research Report 289 (www.ltsa.govt.nz); at www.ltsa.govt.nz/research/reports/289.pdf.

⁴³ Todd Litman and Steven Fitzroy (2008), *Safe Travels: Evaluating Mobility Management Traffic Safety Benefits*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/safetrav.pdf.

⁴⁴ Transport Concepts (October 1994) *External Costs of Truck and Train*, Transport Concepts (Ottawa).

⁴⁵ David Forkenbrock (1999), "External Costs of Intercity Truck Freight Transportation," *Transportation Research A*, Vol. 33, No. 7/8, Sept./Nov. 1999, pp. 505-526.

⁴⁶ National Highway Traffic Safety Administration (www.nhtsa.dot.gov).

⁴⁷ NHTSA (1998), *An Investigation of the Safety Implications of Wireless Communications in Vehicles*, National Highway Traffic Safety Administration (www.nhtsa.dot.gov); at www.nhtsa.dot.gov/people/injury/research/wireless

5.3.4 Active Transportation Health Benefits

Physical Activity refers to physical exercise, which has a major effect on health.⁴⁸ Inadequate physical activity is a major contributor to various health problems listed below. Health experts recommend at least 30 minutes of moderate exercise a day, at least 5 days a week, in intervals of ten-minutes or more.⁴⁹ *Cardiovascular diseases are the leading causes of premature death and disability in developed countries, causing ten times as many lost years of productive life as road crashes.*⁵⁰ Even modest reductions in these illnesses can provide large health benefits.

In *Transport Environment and Health*⁵¹, the World Health Organization states that:

Walking and cycling to work have been shown to meet metabolic criteria for achieving health benefits from exercise. The health benefits of regular sustained physical activity include:

- *a 50% reduction in the risk of developing coronary heart disease (a similar effect to not smoking);*
- *a 50% reduction in the risk of developing adult diabetes;*
- *a 50% reduction in the risk of becoming obese;*
- *a 30% reduction in the risk of developing hypertension;*
- *a 10/8-mmHg decline in blood pressure in people with hypertension (a similar effect to drugs);*
- *reduced osteoporosis;*
- *relief of symptoms of depression and anxiety; and*
- *prevention of falls in the elderly.*

Health risks are associated with cycling and walking, too, the most serious of which are accidents involving cars. Nevertheless, preliminary analysis in the United Kingdom shows that on balance the benefits to life expectancy of choosing to cycle are 20 times the injury risks incurred by that choice.

Transportation decisions can have significant health impacts by affecting people's physical activity.⁵² There are many ways to be physically active, including sports and gym exercise, but these require special time, effort and expenditures, so most people are

⁴⁸ Lawrence Frank, Sarah Kavage and Todd Litman (2006), *Promoting Public Health Through Smart Growth: Building Healthier Communities Through Transportation And Land Use Policies*, Smart Growth BC (www.smartgrowth.bc.ca).

⁴⁹ Surgeon General (1999), *Physical Activity and Health*, Center for Disease Control and Prevention (www.cdc.gov); at www.cdc.gov/nccdphp/sgr/sgr.htm

⁵⁰ Christopher Murray (Ed) (1996), *Global Burden of Disease and Injury*, Center for Population and Development Studies, Harvard University School of Public Health (www.hsph.harvard.edu).

⁵¹ WHO (2000) edited by Carlos Dora and Margaret Phillips, *Transport, Environment and Health* (WHO regional publications. European series ; No. 89). Regional Office for Europe of the World Health Organization (www.euro.who.int) p 30-31; at www.euro.who.int/document/e72015.pdf . Original text includes references to source studies.

⁵² VTPI (2008), "Health and Fitness," *Online TDM Encyclopedia*, (www.vtpi.org); at www.vtpi.org/tdm/tdm102.htm

unlikely to participate regularly in such activities over their lifetime. Many experts believe that *active transportation* (walking, cycling and their variations) is the most practical and effective way to promote public fitness.⁵³ One major study concluded, “Regular walking and cycling are the only realistic way that the population as a whole can get the daily half hour of moderate exercise which is the minimum level needed to keep reasonably fit”.⁵⁴ Some research indicates that automobile dependency can be considered a health risk, while more balanced transportation systems and TDM programs can contribute to improved public health.⁵⁵

Most transit trips involve walking or cycling links, so transit use tends to increase physical activity.^{56 57} Wener and Evans found that train commuters walked an average of 30% more steps per day, reported having walked for a period of 10 minutes or more while traveling significantly more often, and were 4 times more likely to walk 10,000 steps during a day than car commuters.⁵⁸ Travel surveys indicate that the average walking distance involved in a transit trip is five to ten times longer than the average walking distance of an automobile trip. Efforts to encourage transit, reduce driving, and create transit oriented development often improve pedestrian and cycling conditions, which can further increase fitness and health.

Monetizing Health Impacts

Many transport cost studies do not quantify the costs of inactivity or the benefits of active transportation, in effect valuing the benefits of a healthy level of exercise at zero. This is not a minor omission given that cardiovascular diseases cause about ten times as many lost years of productive life as road crashes.⁵⁹ As stated by one expert in non-market costing in reference to environmental costs, “*A crude approximation, made as exact as possible and changed over time to reflect new information, would be preferable to the manifestly unjust approximation caused by ignoring these costs.*”⁶⁰

⁵³ Todd Litman (2002), *If Health Matters: Integrating Public Health Objectives in Transportation Decision-Making*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/health.pdf

⁵⁴ Nick Cavill (2001), “Walking and Health: Making the Links”, *World Transport Policy and Practice*, Vol. 7, No. 4 (www.ecoplan.org/wtpp), pp. 33-38.

⁵⁵ Richard J. Jackson and Chris Kochtitzky (Center of Disease Control) (2001), *Creating A Healthy Environment: The Impact of the Built Environment on Public Health*, Sprawl Watch Clearinghouse (www.sprawlwatch.org); at www.sprawlwatch.org/health.pdf

⁵⁶ Asha Weinstein and Paul Schimek (2005), *How Much Do Americans Walk? An Analysis Of The 2001 NHTS*, Transportation Research Board Annual Meeting (www.trb.org).

⁵⁷ Lilah M. Besser and Andrew L. Dannenberg (2005), “Walking to Public Transit: Steps to Help Meet Physical Activity Recommendations,” *American Journal of Preventive Medicine*, Vol. 29, No. 4 (www.acpm.org); at www.cdc.gov/healthyplaces/articles/besser_dannenberg.pdf

⁵⁸ Richard E. Wener and Gary W. Evans, (2007), “A Morning Stroll: Levels of Physical Activity in Car and Mass Transit Commuting,” *Environment and Behavior*, Vol. 39, No. 1, 62-74 (<http://eab.sagepub.com>); at <http://eab.sagepub.com/cgi/content/abstract/39/1/62>

⁵⁹ Christopher Murray Ed. (1996), *Global Burden of Disease and Injury*, Center for Population and Development Studies, Harvard University School of Public Health (www.hsph.harvard.edu).

⁶⁰ Richard Ottinger (1993), “Incorporating Externalities - The Wave of the Future,” in *Expert Workshop on Lifecycle Analysis of Energy Systems*, OECD Paris, p. 54. (www.oecd.org).

Wherever possible, the health benefits of active transportation and transit projects or activities should be quantified. Likewise the health costs or disbenefits of projects or activities that inhibit active transportation should be estimated and included in any benefit cost analysis.

There are not many studies to draw on for health benefit estimates designed for use in transportation project evaluation. Land Transport New Zealand’s Economic Evaluation Manual (EEM) is one of the few resources to specify monetary values for the health benefits of active transportation resulting from both TDM measures and active transportation infrastructure. This source assumes that half of the benefit is internal to the people who increase their activity level by walking or cycling, and half are external benefits to society such as hospital cost savings. The values for cyclists and pedestrians are shown in the table below.

Table 5.3.4-1 Active Transportation Health Benefits ⁶¹

	2005 \$ NZ/km	2007 USD/km	2007 USD/mile
Cycling	0.16	0.12	0.19
Walking	0.40	0.30	0.48

The US Transportation Research Board *Guidelines for Analysis of Investments in Bicycle Facilities*⁶² seems to be a less useful resource for estimating the full social benefits of active transportation than the New Zealand EEM above. It surveys US health benefits estimates. Each study examines a different range of costs; for example some only cover hospital charges while others include lost productivity as well as medical costs. None of the studies cited attempts to estimate the total of internal and external benefits. The range is extremely wide, from \$19 to \$1,175 per person per year; and the guideline simply uses the median value of \$128 per person year, as shown in the following table.

These sources may underestimate both the true costs of inactivity inducing infrastructure and the true benefits of active transportation. Note that health costs due to air pollution are discussed separately in chapter 5.10.

⁶¹ Land Transport New Zealand (2006 / 2005) *Economic Evaluation Manual (EEM) – volumes 1 & 2* (www.landtransport.govt.nz); at www.landtransport.govt.nz/funding/manuals.html (Active transportation health benefits data is found in Volume 2, section 3.8, p 3-22)

⁶² TRB (2006), *Guidelines for Analysis of Investments in Bicycle Facilities*, NCH Report 552, Transportation Research Board (www.trb.org); at http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_552.pdf

Table 5.3.4-2 Selected Benefits of Increased Activity Per Year

Study/Agency	Per Capita Savings ⁶³
Washington State Department of Health	19
Garrett et al.	57
South Carolina Department of Health	78
Georgia Department of Human Resources	79
Colditz (1999)	92
Minnesota Department of Health	>100
Goetz et al.	172
Pronk et al.	176
Pratt	330
Michigan Fitness Foundation	1,175
<i>Median Value used by TRB – 2006 USD</i>	<i>\$128</i>

The studies cited by the TRB estimate selected benefits of active transportation. Some internal and external benefits are not included.

5.3.5 Personal Security

Personal Security refers to risk of physical assault or theft. Certain transport activities are associated with personal security risks.⁶⁴ Motorists encounter threats such as “road rage” and vehicle thefts, while pedestrians, cyclists and transit passengers sometimes face threats of physical assault or theft. It is difficult to quantify and compare these risks, and since the most sensational incidents receive the most attention (for example, air travel and subway assaults tend to receive considerable media coverage), many people appear to have unrealistic sense of the relative risks of different travel options. Aggressive driving casualties tend to be higher in more automobile dependent regions,⁶⁵ and residents of low-density, exurban areas tend to have greater risk of combined traffic and stranger-murder fatalities, yet many people consider automobile-dependent suburban locations safer than multi-modal urban neighborhoods.⁶⁶

Walking, cycling and transit use tend to decline in areas that are considered insecure, and factors such as street design and maintenance, transit system management and land use policies in an area can affect the quality of personal security. Special efforts to address security concerns can reduce these risks and the perception of risk. Strategies that increase the number of people walking and cycling on streets and paths, and increase community cohesion (including the quality of friendly interactions among neighbors), can increase security in an area.⁶⁷ A significant benefit of addressing security concerns may be the health benefits of active transportation for those who would otherwise stay at inside or drive due to fear of crime.

⁶³ These figure are apparently not adjusted for inflation.

⁶⁴ Federal Transit Administration Office of Safety and Security (www.transit-safety.volpe.dot.gov).

⁶⁵ STPP (1999), *Aggressive Driving: Are You At Risk?* STPP (www.transact.org).

⁶⁶ Alan Durning (1996), *The Car and the City*, Northwest Environment Watch (www.sightline.org); William Lucy (April 2002), *Danger in Exurbia: Outer Suburbs More Dangerous Than Cities*, University of Virginia (www.virginia.edu).

⁶⁷ Bill Hillier & Ozlem Sahbaz (2006), *High Resolution Analysis of Crime Patterns in Urban Street Networks*, University College London; at www.spacesyntax.tudelft.nl/media/Long%20papers%20I/hilliersahbaz.pdf.

Estimates and Studies

Note: monetary units are in U.S. dollars unless indicated otherwise.

5.3.6 Crash Costs

Cost per Distance Study Summary Table

Table 5.3.6-1 Crash Cost Estimate Summary Table – Selected Per Distance Studies

Publication	Costs	Cost Value / Mile (Km)	2007 USD / Mile
Miller 1994	Average Car - Comprehensive	\$0.12 1994 USD	\$0.17
	Bus	\$0.32	\$0.45
	Motorcycle	\$1.50	\$2.10
Cambridge Systematics 2008	Comprehensive - Urban	\$0.25 – 0.41 2005 USD	\$0.27 – 0.43
Parry 2004	External	\$0.022 – 0.066 2004 USD	\$0.02 – 0.07
FHWA 1997	External - Rural	\$0.017 - 0.095	\$0.02 – 0.12
	External - Urban	\$0.008 – 0.040 1997* USD	\$0.01 – 0.05
NHTSA 2002	Market	\$0.086 2000 USD	\$0.10
Wang, Knipling & Blincoe 1999	Comprehensive - Cars	\$0.248 1997 USD	\$0.32
NZ Ministry of Transport 2006	Average – assumed external	\$0.06 2006 NZD / (Km.)	\$0.06

Per mile crash cost estimates vary widely. Studies that only examine external costs produce lower values and comprehensive studies result in higher values. * Indicates that the currency year is assumed to be the same as the study year. More information on these studies and others are found below. See Table 5.3.6-2 below (Émile Quinet) for more comparisons between modes.

Mode & Strategy Comparisons

- 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). The study also suggest that vehicle kilometers traveled (VKT) and safety is so closely correlated that VKT/VMT can sometimes be appropriately used as a proxy for predicting the safety impacts of policies and programs.⁶⁸

⁶⁸ Gordon Lovegrove and Todd Litman (2008), *Macrolevel Collision Prediction Models to Evaluate Road Safety Effects of Mobility Management Strategies: New Empirical Tools to Promote Sustainable Development*, Transportation Research Board 87th Annual Meeting (www.trb.org); at www.vtpi.org/lovegrove_litman.pdf.

- INFRAS Zurich documents external crash costs in Europe per 1000 passenger km. of 37.5 1995 Euros for cars, 3.1 Euros for bus and 0.9 for rail.⁶⁹
- Elvik develops a Benefit-Cost model for evaluating several dozen traffic safety strategies.⁷⁰ He concludes that implementation of all cost-effective safety strategies would reduce crash fatalities by 50-60%, far more than the safety gains that occur with current planning and evaluation practices.
- Émile Quinet summarizes crash costs shown in Table 5.3.6-2. He concludes that crash costs per *passenger mile* is about 10 times higher for cars than for buses.

Table 5.3.6-2 Crash Costs by Travel Mode (U.S. dollars)⁷¹

Study	Location	Passengers (passenger-km)			Freight (tonne-km)		
		Car	Bus	Rail	Road	Rail	Water
Planco, 1990	FRG	0.020	0.004	0.003	0.012	0.008	0.000
Tefra, 1985	France				0.007	0.00	
EcoPlan, 1991	Switzerland	0.030	0.007	0.004	0.070	0.001	
Hansson, 1987	Sweden, Urban	0.050	0.013	0.001	0.013	0.000	
Hansson, 1987	Sweden, Rural	0.088	0.001				

- Table 5.3.6-3 indicates the distribution of fatality risk for various travel modes per 100 million vehicle Km. in the UK.

Table 5.3.6-3 Fatalities per 100 million Veh-Km by Mode in U.K.⁷²

Mode	Vehicle Users	Pedestrians	Other Vehicle Occupants	Total	Percent Non-Users
Bicycle	4.9	0.1	0.1	5.1	4%
Motorbike	10.3	1.7	0.6	12.6	18%
Car	0.7	0.4	0.4	1.5	53%
Light Goods	0.4	0.4	0.6	1.4	71%
Bus	0.4	1.8	1.7	3.9	90%
Heavy Lorry	0.2	0.5	1.9	2.6	93%

⁶⁹ Markus Maibach et al. (March 2000), *External Cost of Transport: Accident, Environmental and Congestion Costs in Western Europe*. INFRAS Zurich / IWW University of Karlsruhe (www.infras.ch), p 60, Table 21.

⁷⁰ Rune Elvik (2003), "How Would Setting Policy Priorities According to Cost-Benefit Analyses Affect the Provision of Road Safety," *Accident Analysis & Prevention*, Vol. 35 (www.elsevier.com/locate/aap), pp. 557-570.

⁷¹ Émile Quinet (1994), "The Social Costs of Transport: Evaluation and Links With Internalization Policies," in *Internalising the Social Costs of Transport*, OECD (www.oecd.org), p.38.

⁷² Mayer Hillman and J. Adams (1995), "Safer Driving - Safer for Whom?," cited in *Urban Travel and Sustainable Development*, OECD (www.oecd.org), p. 54.

- Miller estimates U.S. motor vehicle crash costs totaled \$358 billion in 1988 (\$521 billion in 2000 dollars), a major component of which is pain and lost quality of life.⁷³ The table below shows his estimates of crash costs by vehicle class.

Table 5.3.6-4 Miller’s Estimate of Crash Costs⁷⁴

Mode	1994\$ Per Vehicle Mile	Mode	1994\$ Per Vehicle Mile
Bus	\$0.32	Car (average)	\$0.12
Light Truck	0.19	Car, Drunk Driver	\$5.50
Med/Hay Truck	0.13	Car, Sober Driver	\$0.06
Combination Truck	0.23	Motorcycle	\$1.50

- Analysis by White finds that while drivers view large vehicles as a way to better protect their occupants (internal benefits), in the event of an accident those same larger vehicles pose a greater danger to occupants of smaller vehicles and to pedestrians and bicyclists (external costs).⁷⁵ When drivers replace cars with light trucks, 3,700 additional crashes per year involving fatalities of smaller vehicle occupants, pedestrians, and bicyclists occur, while only 1,400 crashes involving fatalities of light truck occupants are avoided. This produces a ratio of negative external effects to positive internal effects of 2.5 to 1.
- Gaudry analyzes Canadian and German data on the mode mix among crashes involving different degrees of severity to evaluate how drivers trade-off risks of different types of accidents (for example, safety devices such as seatbelts and airbags reduce severe injuries and fatalities, but not property damages), revealing the value people place on injury or death risks.⁷⁶ He concludes that current official monetized crash values are lower than what consumers actually place on injury reduction.

North America

- The 2008 study *Crashes vs. Congestion - What's the Cost to Society?*, commissioned by the American Automobile Association compared crash and congestion costs in major U.S. cities using Federal Highway Administration crash costs and the Texas

⁷³ Ted Miller (1991), *The Costs of Highway Crashes*, FHWA (www.fhwa.dot.gov); pub. No. FHWA-RD-055, 1991.

⁷⁴ Ted Miller (1994), Presentation at FHWA Colloquium on Social Costs of Transportation, 12 Dec. 1994, Washington DC; Miller, et al. (1994), “Railroad Injury: Causes, Costs, and Comparisons with Other Transport Modes,” *Journal of Safety Research*, Vol. 25, No. 4 (www.elsevier.com/locate/jsr), pp. 183-195.

⁷⁵ Michael White (2005), “The “Arms Race” on American Roads: The Effect of Sport Utility Vehicles and Pickup Trucks on Traffic Safety,” *Journal of Law and Economics*, Vol. 47 (www.journals.uchicago.edu/JLE/journal), Oct. 2005, pp. 333-355.

⁷⁶ Marc Gaudry (2002), *Life, Limb and Bumper Trade-Offs Calculable from Road Accident Models: a Note on a Multimoment Portfolio Analysis and Life Asset Pricing Model (LAPM)*, Club of Jules Dupuit, University of Montreal (www.ajd.umontreal.ca), July 2002.

Transportation Institute’s *Urban Mobility Study* congestion costs.⁷⁷ It found that crash costs average more than twice congestion costs. Per capita crash costs decrease with increased city size, which is the inverse of congestion costs. Urban crash costs are estimated to average 25¢-41¢ per vehicle mile. Note that this study examines the comprehensive cost of crashes and therefore reports higher values than sources which only cover selected or external costs.

- Edlin and Karaca-Mandic estimate auto accident externalities (more specifically insurance externalities) using panel data on state-average insurance premiums and loss costs.⁷⁸ They find substantial externalities in dense states. In California, for example, they find that a typical additional driver increases the total of other people’s insurance costs by \$2,231 per year. In contrast, the accident externality per driver in lower density states is much smaller. A Pigouvian tax to collect accident externalities in the U.S. could raise over \$140 billion nationally.
- Hanley surveyed U.S. state departments of transportation to determine the crash cost values used for traffic safety evaluation. The table below summarizes the results.

Table 5.3.6-5 DOT Crash Cost Values⁷⁹

State	Fatal	Injury	PDO
Texas	\$1,191,887	\$69,199	\$1,969
Wisconsin	\$1,057,000	\$50,300	\$6,600
Illinois	\$1,040,000	\$36,000	\$6,500
North & South Dakota	\$1,040,000	\$36,500	\$6,500
Connecticut	\$1,040,000	\$36,500	\$6,500
Michigan	\$1,000,000	\$35,300	\$6,500
Ohio	\$987,977	\$39,258	\$6,480

⁷⁷ Cambridge Systematics (2008), *Crashes vs. Congestion - What's the Cost to Society?*, American Automobile Association (www.aaa.com); at www.aaanewsroom.net/Assets/Files/20083591910.CrashesVsCongestionFullReport2.28.08.pdf

⁷⁸ Aaron S. Edlin and Pinar Karaca Mandic (2001), *The Accident Externality from Driving*, University of California, Berkeley (http://works.bepress.com/aaron_edlin/21).

⁷⁹ Paul F. Hanley (2005), State Departments of Transportation’s Use of Crash Costs in Safety Analysis, TRB Annual Meeting (www.trb.org).

- The National Safety Council published two monetized estimates of motor vehicle crash costs, as summarized in the table below. One only includes productivity costs, including lost wage, medical expenses, administrative expenses, motor vehicle damage, and employers’ uninsured costs. The other estimates comprehensive costs, including victims pain and people’s willingness to pay to avoid such injuries.

Table 5.3.6-6 Crash Costs by Severity (2004 U.S. dollars) ⁸⁰

	Economic Productivity Costs	Comprehensive Costs
Death	\$1,130,000	\$3,760,000
Non-fatal disabling injury	\$49,700	\$188,000
Nonincapacitating evident injury		\$48,200
Possible injury		\$22,900
Property damage crash (including nondisabling injuries)	\$7,400	\$2,100

- Parry calculates total and external accident costs, and the portion of these costs that are borne by insurance. The table below summarizes his estimate of different types of costs for various accident severities. “Quality of life costs” represent the value of non-monetary costs such as pain, grief and reduced enjoyment due to deaths and injuries.

Table 5.3.6-7 Crash Costs by Severity (2004 U.S. dollars) ⁸¹

	Fatal Injury	Disabling Injury	Evident Injury	Possible Injury	Property Damage Only
Medical	\$22,095	\$19,471	\$5,175	\$3,485	\$140
Household Productivity	0	\$6,944	\$1,854	\$1,244	\$85
Lost Wages	0	\$25,014	\$6,239	\$4,160	\$155
Legal Costs	\$102,138	\$5,167	\$1,101	\$681	\$15
Insurance Administration	\$37,120	\$5,999	\$1,776	\$1,181	\$152
Property Damage	\$10,273	\$4,357	\$3,824	\$3,413	\$1,642
Police & Fire Services	\$833	\$175	\$112	\$90	\$31
Travel Delay	\$5,247	\$885	\$797	\$785	\$696
Employer Costs	0	\$1,679	\$665	\$461	\$67
<i>Total, Excluding Quality of Life Costs</i>	<i>\$186,480</i>	<i>\$69,479</i>	<i>\$21,543</i>	<i>\$15,500</i>	<i>\$2,983</i>
Quality of Life Costs	\$3,000,000	\$83,239	\$19,560	\$10,725	\$464
<i>Total, Including Quality of Life Costs</i>	<i>\$3,186,408</i>	<i>\$152,718</i>	<i>\$41,103</i>	<i>\$26,225</i>	<i>\$3,447</i>

Table 5.3.6-8 summarizes low, medium and high estimates of the external accident costs of driving. This indicates that external costs range from 2.2¢ to 6.59¢ per vehicle mile, representing 18% to 54% of total \$300 billion estimated total crash costs.

⁸⁰ NSC (2005), *Estimating the Costs of Unintentional Injuries, 2004*, National Safety Council (www.nsc.org).

⁸¹ Ian W. H. Parry (2004), “Comparing Alternative Policies to Reduce Traffic Accidents,” *Journal of Urban Economics*, Vol. 54, No. 2, Sept. 2004, pp. 346-368, Table 2.

Table 5.3.6-8 External Crash Costs (2004 U.S. Cents Per Vehicle-Mile)⁸²

	Low	Medium	High
Pedestrian & Cyclist Deaths	0.56¢	0.56¢	0.56¢
Pedestrian & Cyclist Injuries	0.21¢	0.21¢	0.21¢
Other Vehicle Deaths	0.00¢	0.81¢	1.62¢
Other Vehicle Injuries	0.00¢	0.84¢	1.69¢
Property Damages	0.15¢	0.30¢	0.44¢
Traffic Holdups	0.17¢	0.17¢	0.17¢
Medical, Emergency Services, Legal, Etc.	1.07¢	1.07¢	1.07¢
Wages/Household Production	0.05¢	0.44¢	0.84¢
<i>Total (cents/mile)</i>	2.20¢	4.39¢	6.59¢
<i>Total (billion dollars)</i>	\$54	\$109	\$163

- Table 5.3.6-9 summarizes marginal external crash costs (costs imposed on pedestrians, expenses not paid by drivers as a class, and the incremental risk of crashes associated with marginal increases in traffic volumes) for various vehicles and conditions, estimated for the *1997 Federal Highway Cost Allocation Study*.

Table 5.3.6-9 Estimated Highway External Crash Costs (Cents Per Vehicle Mile)⁸³

	Rural Highways			Urban Highways			All Highways		
	High	Med.	Low	High	Med.	Low	High	Med.	Low
Automobile	9.68	3.15	1.76	4.03	1.28	0.78	6.02	1.94	1.13
Pickup & Van	10.21	3.31	1.75	4.05	1.27	0.74	6.70	2.15	1.17
Buses	14.15	4.40	2.36	6.25	1.89	1.08	9.55	2.94	1.62
Single Unit Trucks	5.97	2.00	0.97	2.21	0.71	0.40	3.90	1.29	0.65
Combination Trucks	6.90	2.20	1.02	3.67	1.16	0.56	5.65	1.79	0.84
<i>All Vehicles</i>	<i>9.52</i>	<i>3.09</i>	<i>1.68</i>	<i>3.98</i>	<i>1.26</i>	<i>0.76</i>	<i>6.12</i>	<i>1.97</i>	<i>1.11</i>

- The Alberta Medical Association estimated that in 1999 traffic crash costs in Alberta, Canada total \$3.8 billion (1998 Canadian dollars), based on a value of \$2.9 million per fatality, \$100,000 per injury, and \$8,000 for each property-damage-only collision.⁸⁴ This averages about \$515 dollars per capita (\$335 U.S.), \$740 per motor vehicle (\$471), and 3.7¢ per motor vehicle-kilometre (4.0¢ U.S. per vehicle-mile).
- Apogee Research estimates that total crash costs average 1.2¢ per passenger-mile for automobile expressway driving, and 6.3¢ on surface streets, suggesting that surface street driving has about five times the crash costs per mile as highway driving.⁸⁵

⁸² Parry, 2004, Table 6.

⁸³ FHWA (1997), *1997 Federal Highway Cost Allocation Study*, USDOT (www.dot.gov), Table V-24; at www.fhwa.dot.gov/policy/hcas/summary/index.htm

⁸⁴ Mark Anielski (2001), *Alberta GPI Accounts: Auto Crashes and Injuries*, Pembina Institute (www.pembina.org), Dec. 2001.

⁸⁵ Apogee Research (1994) *The Costs of Transportation: Final Report*, Conservation Law Foundation (www.clf.org), p. 112-118.

- A National Highway Traffic Safety Administration study uses the Human Capital method (which measures only market costs such as property damage, medical treatment, and lost productivity) to estimate that U.S. crash financial costs totaled about \$231 billion in 2000, averaging about 8.6¢ per vehicle mile.⁸⁶ Of these costs, approximately three-quarters are considered external to individual drivers involved in a crash. Appendix A of the report also incorporates Quality-Adjusted Life Years (QALYs), which reflect non-market costs such as pain, grief and reduced quality of life. The table below lists the cost categories included in this analysis and their estimated average values for various crash severity ratings. The last row indicates the ratio of non-market costs (QALY) to market costs.

Table 5.3.6-10 NHTSA Estimate of Crash Costs (2000)⁸⁷

Injury Severity	PDO	MAIS 0 None	MAIS 1 Minor	MAIS 2 Moderate	MAIS 3 Serious	MAIS 4 Severe	MAIS 5 Critical	FATAL Fatal
Medical	\$0	\$1	\$2,380	\$15,625	\$46,495	\$131,306	\$332,457	\$22,095
Emergency Services	\$31	\$22	\$97	\$212	\$368	\$830	\$852	\$833
Market Productivity	\$0	\$0	\$1,749	\$25,017	\$71,454	\$106,439	\$438,705	\$595,358
HH Productivity	\$47	\$33	\$572	\$7,322	\$21,075	\$28,009	\$149,308	\$191,541
Insurance Administration	\$116	\$80	\$741	\$6,909	\$18,893	\$32,335	\$68,197	\$37,120
Workplace Costs	\$51	\$34	\$252	\$1,953	\$4,266	\$4,698	\$8,191	\$8,702
Legal Costs	\$0	\$0	\$150	\$4,981	\$15,808	\$33,685	\$79,856	\$102,138
Injury Subtotal	\$245	\$170	\$5,941	\$62,019	\$178,359	\$337,302	\$1,077,566	\$957,787
Travel Delay	\$803	\$773	\$77	\$846	\$940	\$999	\$9,148	\$9,148
Property Damage	\$1,484	\$1,019	\$3,844	\$3,954	\$6,799	\$9,833	\$9,446	\$10,273
Non-Injury Subtotal	\$2,287	\$1,792	\$4,621	\$4,800	\$7,739	\$10,832	\$18,594	\$19,421
Market Cost Summary	\$2,532	\$1,962	\$10,562	\$66,820	\$186,097	\$348,133	\$1,096,161	\$977,208
QALY (Nonmarket)	\$0	\$0	\$4,455	\$91,137	\$128,107	\$383,446	\$1,306,836	\$2,389,179
Total Comprehensive	\$0	\$0	\$15,017	\$157,958	\$314,204	\$731,580	\$2,402,997	\$3,366,388
<i>Non-market/Market</i>	<i>0.00</i>	<i>0.00</i>	<i>0.42</i>	<i>1.36</i>	<i>0.69</i>	<i>1.10</i>	<i>1.19</i>	<i>2.44</i>

PDO means “Property Damage Only.” MAIS means maximum injury severity level by victims.

⁸⁶ Lawrence Blincoe, et al. (2002), *Economic Cost of Motor Vehicle Crashes 2000*, NHTSA, USDOT (www.nhtsa.dot.gov), Report DOT HS 809 446, 2002.

⁸⁷ Blincoe, et al (2002), *ibid.* See original document for definitions.

- Table 5.3.6-11 shows average costs values for two scales used to rate crash severity.

Table 5.3.6-11 FHWA Crash Costs Per Injury (1994 dollars)⁸⁸

KABC Scale			Abbreviated Injury Scale (AIS)		
Severity	Descriptor	Cost	Severity	Descriptor	Cost
K	Fatal	\$2,600,000	AIS 6	Fatal	\$2,600,000
A	Incapacitating	\$180,000	AIS 5	Critical	\$1,980,000
B	Evident	\$36,000	AIS 4	Severe	\$490,000
C	Possible	\$19,000	AIS 3	Serious	\$150,000
PDO	Property Damage Only	\$2,000	AIS 2	Moderate	\$40,000
			AIS 1	Minor	\$5,000

- Analysis of U.S. crashes finds that light trucks and SUVs are more likely to be involved in rollover crashes, are less likely to be injured in a crash with another vehicle, but occupants of the vehicles they hit are more likely to be injured.⁸⁹
- The National Highway Institute publishes estimates of crash costs by roadway type, indicating costs averaging about 7¢ per vehicle-mile on separated highways, and about 21¢ per vehicle-mile on other roads.⁹⁰
- 1998 Michigan traffic crashes are estimated to cause \$4.3 billion in monetary costs (4.8¢ per mile) and \$10.7 billion in total costs (11.8¢ per mile).⁹¹ The table below shows the estimated cost values used in this study.

Table 5.3.6-12 Costs Per Police Reported Crash Victim in Michigan (1997 dollars)

	Fatal	Serious Injury	Moderate Injury	Minor Injury	Property Damage Only
Medial Care	22,254	17,464	3,823	2,051	68
Future Earnings	1,053,152	23,563	7,786	3,876	319
Public Services	1,275	314	204	133	29
Property Losses	11,901	4,683	3,980	3,008	1,257
<i>Subtotal (Monetary Losses)</i>	<i>1,088,592</i>	<i>46,025</i>	<i>15,793</i>	<i>9,067</i>	<i>1,672</i>
Quality of Life	2,093,660	113,992	25,566	10,647	244
<i>Total</i>	<i>3,182,252</i>	<i>160,016</i>	<i>41,359</i>	<i>19,714</i>	<i>1,916</i>

⁸⁸ FHWA (1994), *Motor Vehicle Accident Costs - Technical Advisory*, T 7570.2, Federal Highway Administration, (www.fhwa.dot.gov); at www.fhwa.dot.gov/legsregs/directives/techadvts/t75702.htm

⁸⁹ Kara Maria Kockelman and Young-Jun Kweon (2002), “Driver Injury Severity,” *Accident Analysis and Prevention*, Vol. 34, No. 3 (www.elsevier.com/locate/inca/336), pp. 313-321; at www.ce.utexas.edu/prof/kockelman/home.html.

⁹⁰ NHI (1995), *Estimating the Impacts of Urban Transportation Alternatives, Participant’s Notebook*, National Highway Institute, Federal Highway Admin. (www.fhwa.dot.gov), Course #15257, Dec. 1995, p. VI-28.

⁹¹ Fredrick M. Streff and Lisa J. Molnar (1999), *Societal Costs of Traffic Crashes and Crime in Michigan: 1998 Update*, University of Michigan Transportation Research Institute (www.umtri.umich.edu).

- A study by Wang, Knipling and Blincoe using the Comprehensive method of costing crash damages (including non-market costs, such as pain and grief) concludes that U.S. crash costs totaled \$432 billion in 1997, averaging about 20¢ per vehicle mile.

Table 5.3.6-13 U.S. Crash Data and Estimated Crash Costs (1997 U.S. Dollars)⁹²

	All Vehicles	Passenger Cars	Light Trucks/Vans	Combination Trucks	Single Unit Trucks	Motorcycles
Police Reported Crashes	6,261,000	5,307,000	2,209,000	214,000	154,000	89,000
Minor-Moderate Injuries	3,433,000	3,020,000	1,183,000	85,000	65,000	78,000
Serious-Fatal Injuries	194,000	146,000	65,000	9,000	5,000	15,000
Per 100 Million VMT	500	556	416	226	289	928
Per 1000 Veh. (annual)	59	65	48	135	36	22
Comp. Cost Per Crash	\$52,610	\$50,190	\$50,750	\$89,400	\$66,370	\$206,460
Comp. Cost Per VMT	\$0.197	\$0.248	\$0.247	\$0.226	\$0.215	\$2.331
Comp. Cost Per Veh. Year	\$2,340	\$2,900	\$2,850	\$13,520	\$2,720	\$5,410

This summarizes crash data. Additional information is provided in the original table.

- The U.S. Department of Transportation published a guidance memorandum recommending that each avoided accident fatality be valued at \$3.0 million dollars, with a 7% annual discount rate for depreciating future costs.⁹³

Australia and New Zealand

- The total cost of road crashes in Australia in 1996 has been conservatively estimated at approximately \$15 billion (1996 Australian dollars).⁹⁴ This includes vehicle and other property damages, emergency services, traffic delays, medical costs, lost of productivity due to disabilities and lost quality of life. The average cost of a fatality was \$1.5 million, a serious injury \$325,000 and a minor injury \$12,000. The average cost per crash (all injury levels) was \$24,000. The average cost of a fatal crash was \$1.7 million; serious injury crash, \$408,000; minor injury crash, \$14,000; and property damage only crash (PDO), \$6,000.
- A New Zealand Ministry of Transport study calculates that motor vehicle crashes impose social costs totaled approximately \$4.1 billion in 2005 (averaging about \$1,000 per capita or about 6¢ per vehicle-kilometer) in 2006 New Zealand dollars.⁹⁵ This included \$1,241 million for fatalities, \$1,353 million for serious injuries, \$713 million for minor injuries and \$800 million for property damages.

⁹² Jing-Shiarn Wang, Ronald R. Knipling and Lawrence J. Blincoe (1999), “The Dimensions of Motor Vehicle Crash Risk, *Journal of Transportation and Statistics*, Vol. 2, No. 1 (www.bts.gov), May 1999, pp. 19-43.

⁹³ USDOT (2002), *Treatment of Value of Life and Injuries in Preparing Economic Evaluations*, U.S. Department of Transportation (www.dot.gov); at http://ostpxweb.dot.gov/VSL_background.htm

⁹⁴ BRTRE (2000), *Road Crash Costs in Australia*, Report 102, Bureau of Transport and Regional Economics (www.btre.gov.au).

⁹⁵ NZMT (2006), *The Social Cost Of Road Crashes And Injuries - June 2006 Update*, New Zealand Ministry of Transport (www.transport.govt.nz); available at www.transport.govt.nz/assets/NewPDFs/NewFolder/Social-cost-June-2006-update.pdf

Europe and UK

- A study for the European Union provides the following estimates of traffic crash costs.

Table 5.3.6-14 Crash Costs (2003 Euros)⁹⁶

	Lost Output	Human Costs	Medical Costs	Property Damage	Insurance Admin.	Police Costs	Delay Costs	Total Costs
Fatal Crash	598,408	1,150,000	8,056	11,172	314	1,999	15,000	1,789,754
Injury Crash	6,632	35,000	3,524	3,445	130	91	5,000	53,736
Individual Fatality	520,355	1,000,000	7,005	NA	NA	NA	NA	1,527,360
Individual Injury	4,877	26,000	2,591	NA	NA	NA	NA	33,468

NA = Not Applicable

- Jansson calculates marginal crash costs motor vehicles impose on unprotected road users (pedestrians, bicyclists, and motorcyclists) based on various estimates of the relationship between crashes and vehicle mileage, shown in the table below.

Table 5.3.6-15 Crash Costs to Unprotected Road Users by Jan Jansson (\$/km)⁹⁷

Crash/VMT Ratio	Unprotected Road User Crashes Per 100M Motor Vehicle Km		
	10	20	30
1/3	\$0.02	\$0.04	\$0.06
2/3	\$0.04	\$0.08	\$0.12
1/1	\$0.06	\$0.12	\$0.18

This table shows the crash costs automobiles impose on unprotected road users with three crash rates and three ratios of crash rate to motor vehicle travel volume.

- The table below shows external crash costs estimated by David Maddison, et al.

Table 5.3.6-16 Marginal External Costs of Road Traffic Crashes in Great Britain⁹⁸

	1993 Pence Per Km	1996 US\$ Per Mile
Unprotected Road Users	0.6-1.1	\$0.016-0.029
Protected Road Users	0.1-1.2	\$0.003-0.031
Total	0.7-2.3	\$0.018-\$0.06

- European motor vehicle crash costs are estimated to average 6-13 ECUs per 1,000 automobile km (U.S. 1.3-2.9¢ per mile), about two thirds of which are external.⁹⁹

⁹⁶ ICF Consulting (2003), *Cost-Benefit Analysis of Road Safety Improvements*, European Union (http://europa.eu/index_en.htm); at http://europa.eu.int/comm/transport/road/library/icf_final_report.pdf

⁹⁷ Jan Jansson (1994), "Crash Externality Charges," *Journal of Transport Eco. and Policy* (www.bath.ac.uk/e-journals/jtep), Jan. 1994, p. 40.

⁹⁸ David Maddison, et al (1996), *The True Costs of Road Transport*, Earthscan (London), 1996, p. 133.

⁹⁹ Ulf Persson and Knut Ödegaard (1995), "External Cost Estimates of Road Traffic Crashes; An International Comparison," *Journal of Transport Economics and Policy* (www.bath.ac.uk/e-journals/jtep), September 1995, pp. 291-304.

- The COBA model (the standard benefit-cost analysis framework for evaluating transport improvements in the UK) uses the crash cost values in the table below

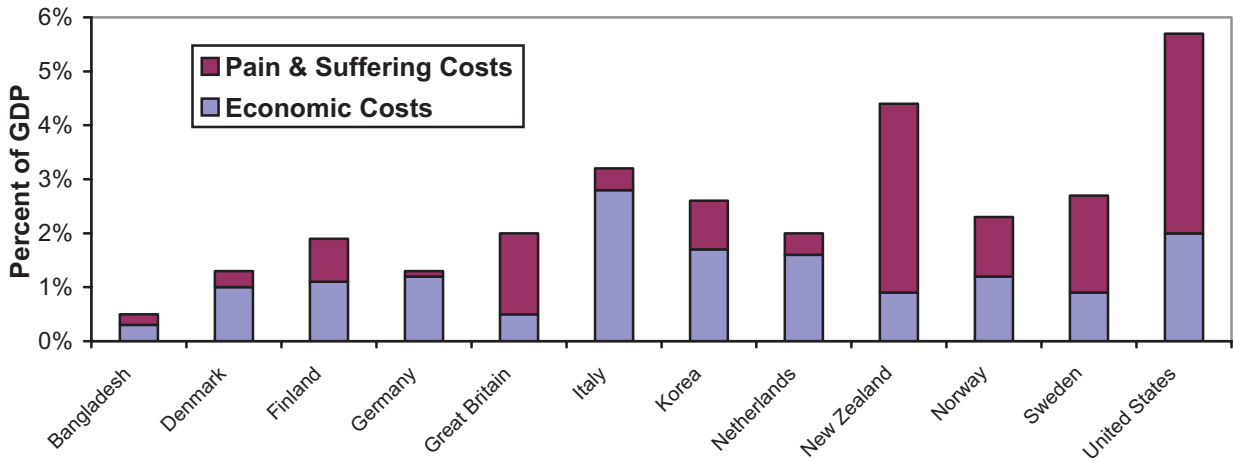
Table 5.3.6-17 Crash Cost Values Used by U.K. COBA Model (1994 Pounds)¹⁰⁰

Type	Casualty	Insurance	Property Damage			Police Costs		
			Urban	Rural	Motorway	Urban	Rural	Motorway
Fatal	£784,090	£163	£4,224	£7,165	£9,114	£1,034	£980	£1,435
Serious	£98,380	£101	£2,264	£3,266	£7,776	£87	£242	£226
Slight	£6,920	£62	£1,336	£2,165	£3,934	£31	£31	£31
Damage only		£29	£956	£1,427	£1,372	2	£2	£2

Global & International Comparisons

- Elvik estimates road accident costs measured as a percentage of gross national product (GDP) for twelve countries based on previous studies. Excluding non-market impacts (pain and suffering), these costs are estimated to average 1.3% of GDP, with a range of 0.3-2.8%; and when a non-market costs are included, they are estimated to average 2.5% of GDP, with a range of 0.5-5.7%. Figure 5.3.6-1 shows the results.¹⁰¹

Figure 5.3.6-1 Crash Costs as Portion of GDP (Elvik, 2002)



This figure illustrates traffic crash costs as a portion of GDP for various countries.

¹⁰⁰ R. Vickerman (2000), "Evaluation Methodologies for Transport Projects in the United Kingdom," *Transport Policy*, Vol. 7, No. 1, January 2000, pp. 7-12.

¹⁰¹ Rune Elvik (2002), "How Much do Road Accidents Cost the National Economy?," *Accident Analysis & Prevention*, Vol. 34 (www.elsevier.com/locate/aap), 2002, pp. 849-851.

- Kopits and Cropper estimates that worldwide, about 720,000 people currently die annually in traffic crashes and this will likely increase to about 1.2 million annual deaths in 2020.¹⁰² They estimate that worldwide only about 50% of road injuries are reported, and there are about 100 injuries for each traffic fatality.
- Mohan estimates India traffic crash cost total 1,772,183 million Rupees, or more than 2% of GDP, which is similar to OECD countries.¹⁰³ Table 5.3.6-18 shows his summary of international cost estimates. Table 5.3.6-19 summarizes the estimate for India.

Table 5.3.6-18 International Crash Cost Estimates (Mohan, 2002)

Country	Year	Portion GDP	Value US\$ mil (1997)	Source
Latin America				
Brazil	1997	2.0%	\$15,681	IADB Review of Traffic Safety
Asia				
Vietnam	1998	0.3%	72	Technical Note: Accident Costing
Bangladesh	1998	0.5%	220	IDC Economics Working Paper
Thailand	1997	2.3%	3,810	SWEROAD Road Safety Master Plan
Korea	1996	2.6%	12,561	Elvik, 1999
Nepal	1996	0.5%	24	Road Maintenance Component, TN Accident Costing
Kerala, India	1993	0.8%	--	Chand "Cost of Road Accidents in India"
Indonesia	1995	--	691-958	Accident Cost in Indonesia: TRL/IRE
Africa				
KwaZulu Natal	199?	4.5%	--	Kwazulu-Natal Road Traffic Safety Strategy
Tanzania	1996	1.3%	86	Road Safety Program Tanzania Ministry of Works
Zambia	1990	2.3%	189	TOI Study
Malawi	1995	<0.5%	106	SWK/Iberinsa Road Safety Study
Egypt	1993	0.8%	577	Aly, "Valuation of Traffic Accidents in Egypt"
High Income				
UK	1998	2.1%	28,856	Road Accidents Great Britain.
Sweden	1995	2.7%	6,261	Elvik, 1999
Norway	1995	2.3%	3,656	Elvik, 1999
Iceland	1995	3-4%	7,175	Arnason, Nordic Road & Transport Research
USA	1994	4.6%	358,022	NHTSA Technical Report
Germany	1994	1.3%	30,173	Elvik, 1999
Denmark	1992	1.1%	2,028	Elvik, 1999

¹⁰² Elizabeth Kopits and Maureen Cropper (2003), *Traffic Fatalities and Economic Growth*, World Bank Research Working Paper 3035 (www.worldbank.org).

¹⁰³ Dinesh Mohan (2002), *Social Cost of Road Traffic Crashes in India*, Proceedings First Safe Community Conference on Cost of Injury, Viborg, Denmark, pp 33-38, Indian Institute of Technology (www.iitd.ernet.in); at www.iitd.ernet.in/tripp/publications/paper/safety/dnmrk01.PDF

Table 5.3.6-19 India Estimate of Crash Costs (Mohan, 2002)

Severity	Number of Victims	Estimated Cost in 1995 Rs
Fatalities	71,948	38,527,362,572
Serious-Major Injuries	1,079,220	188,698,379,340
Minor Injuries	5,036,360	94,960,567,800
Totals	6,187,528	322,186,311,707

- A major Harvard School of Public Health study finds that traffic crashes are the eighth leading cause of death and disability in developed countries, and the tenth in developing countries.¹⁰⁴ Among adults aged 15-44, traffic crashes are the leading cause of injury death for men and the fifth leading cause for women. The study projects that if present trends continue traffic crashes will become the third most common cause of death worldwide.
- A World Health Organization study estimates that approximately 1.26 million humans lost their lives in 2000 as a result of road traffic incidents, making road crashes the single leading cause of injury deaths worldwide.¹⁰⁵

Methodology

- Land Transport NZ's Economic Evaluation Manual (EEM) outlines standards for the economic evaluation of both transportation infrastructure projects and transportation demand management (TDM) measures, including crash costs. It includes worksheets, and software which is available for download.¹⁰⁶
- The *Highway Economic Requirements System* developed by the FHWA to evaluate highway improvement needs and benefits includes guidance on crash cost analysis, monetization of crash costs, and factors affecting crash rates.¹⁰⁷
- van Essen, et al describe various method that can be used to calculate crash externalities.¹⁰⁸ They recommend the *risk externality* method, which involves these four steps:
 1. Estimate the risk for injurers (user that causes the accident) and victims (user that suffers from accidents).
 2. Apply risk elasticity. For this one estimates the relationship between traffic volume and accident frequency; and calculate the marginal increase of the expected number of accidents. For example if traffic volumes increase with 5%, accident levels will

¹⁰⁴ Christopher Murray (Ed) (1996), *Global Burden of Disease and Injury*, Center for Population and Development Studies, Harvard School of Public Health (www.hsph.harvard.edu), Nov. 1996.

¹⁰⁵ WHO (2003), *The Injury Chartbook*, World Health Organization (www5.who.int).

¹⁰⁶ Land Transport New Zealand (2006 / 2005) *Economic Evaluation Manual (EEM) – volumes 1 & 2* (www.landtransport.govt.nz); at www.landtransport.govt.nz/funding/manuals.html

¹⁰⁷ FHWA (2002), *Highway Economic Requirements System: Technical Report*, Federal Highway Administration, (www.fhwa.dot.gov); at <http://isddc.dot.gov/OLPFiles/FHWA/010945.pdf>

¹⁰⁸ van Essen, et al (2004), *Marginal Costs of Infrastructure Use – Towards a Simplified Approach*, CE Delft; results published in Vermeulen, et al (2004), *The Price of Transport: Overview of the Social Costs of Transport*, CE Delft (www.ce.nl).

increase with 2%. Information on risk elasticity will be taken from case-studies, literature review or planning models. The risk elasticity only focuses on the relationship between traffic volume and accident frequency. Other ‘risk drivers’ like time-of-day, speed, gender etc. are taken into account in the determination of the risk for injurers and victims in the first step of the methodology.

3. Evaluate the monetary value of these changes by the means of willingness-to-pay/avoid method. The so-called value of statistical life (VOSL) is a term often used to express the individual’s willingness-to-pay for safety. The marginal cost is the change in the frequency of accidents multiplied by the costs per occurrence.
4. Estimate the portion of added cost that are internal and external by correcting these costs for paid compensation and fines that are internal costs. The difference between the marginal accident costs and internal/private costs gives external marginal accident costs.

5.3.7 Active Transportation Health Benefits

- Land Transport NZ's Economic Evaluation Manual (EEM) outlines standards for the economic evaluation of both transportation infrastructure projects and transportation demand management (TDM) measures in New Zealand. Of particular note is that this is one of the few resources to specify monetary values for the health benefits of active transportation resulting from both TDM measures and active transportation infrastructure. This source assumes that half of the benefit is internal to the people who increase their activity level by walking or cycling, and half are external benefits to society such as hospital cost savings.

Table 5.3.7-1 Active Transportation Health Benefits ¹⁰⁹

	2005 \$ NZ/km	2007 USD/km	2007 USD/mile
Cycling	0.16	0.12	0.19
Walking	0.40	0.30	0.48

- The Transportation Research Board (2006) *Guidelines for Analysis of Investments in Bicycle Facilities*¹¹⁰ surveys US health benefits estimates. Each study examines a different range of costs, for example some only cover hospital charges while others include lost productivity as well as medical costs. None of the studies cited attempts to estimate the total of internal and external benefits. The range is from \$19 to \$1,175 per person per year, and the TRB guideline uses the median value of \$128 per person year as shown in the table below.

¹⁰⁹ Land Transport New Zealand (2006 / 2005) *Economic Evaluation Manual (EEM) – volumes 1 & 2* (www.landtransport.govt.nz); at www.landtransport.govt.nz/funding/manuals.html (Active transportation health benefits data is found in Volume 2, section 3.8, p 3-22)

¹¹⁰ Transportation Research Board (2006), *Guidelines for Analysis of Investments in Bicycle Facilities*, NCH Report 552. (www.trb.org); at http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_552.pdf

Table 5.3.7-2 Selected Benefits of Increased Activity Per Year

Study/Agency	Per Capita Savings ¹¹¹
Washington State Department of Health	19
Garrett et al.	57
South Carolina Department of Health	78
Georgia Department of Human Resources	79
Colditz (1999)	92
Minnesota Department of Health	>100
Goetz et al.	172
Pronk et al.	176
Pratt	330
Michigan Fitness Foundation	1,175
Median Value used by TRB	\$128

The studies cited by the TRB only attempt to estimate selected benefits of active transportation, not the full internal and external benefits.

- In *Transport Environment and Health*¹¹², the World Health Organization lists the health benefits of regular exercise such as active transportation:
 - a 50% reduction in the risk of developing coronary heart disease (a similar effect to not smoking);
 - a 50% reduction in the risk of developing adult diabetes;
 - a 50% reduction in the risk of becoming obese;
 - a 30% reduction in the risk of developing hypertension;
 - a 10/8-mmHg decline in blood pressure in people with hypertension (a similar effect to drugs);
 - reduced osteoporosis;
 - relief of symptoms of depression and anxiety; and
 - prevention of falls in the elderly.

5.3.8 Variability

Crash rates vary significantly with driver behavior, vehicle type and travel conditions. Although crash rates are higher in urban areas due to increased traffic density, crash severity and fatality rates are higher for rural travel, so crash costs per vehicle-mile are approximately equal.

5.3.9 Equity and Efficiency Issues

Some crash costs are internal at the individual level (borne directly by the individual that imposes them), some are external to the individual but borne by other motorists (such as

¹¹¹ These figure are apparently not adjusted for inflation and instead reflect the nominal values in the year of each study cited.

¹¹² WHO (2000) edited by Carlos Dora and Margaret Phillips, *Transport, Environment and Health* (WHO regional publications. European series ; No. 89). Regional Office for Europe of the World Health Organization (www.euro.who.int) p 30-31; at www.euro.who.int/document/e72015.pdf . Original text includes references to source studies.

insurance compensation costs), and others are external (imposed on other types of road users, or on society in general). Crash costs raise several equity issues:

- Fairness of motorists imposing risks on vulnerable road users, who are often less privileged than motorists.
- Fairness of higher-risk motorists (inexperienced drivers, drivers who talking on a telephone, motorists with faulty brakes, etc.) imposing risks on other road users.
- Fairness of motorists with larger vehicles imposing risks on motorists with smaller vehicles.
- Fairness of insurance compensation practices (victims who feel inadequately compensated).
- Fairness of requiring motorists to carry liability insurance, which makes driving unaffordable to some people, and the fairness of existing insurance pricing.

To the degree that a portion of crash costs are external (not borne directly by the individual road user that causes them), and to the degree that vehicle insurance does not accurately reflect each motorists' insurance costs, crash cost pricing is inefficient.

The health benefits of active transportation raise equity and efficiency issues such as:

- Fairness of motorists inhibiting healthy levels of exercise by people traveling by active modes.
- Efficiency of the amount of public resources and land devoted to automobile travel as compared to active transportation modes.

5.3.10 Conclusions

Crashes impose significant costs on individual road users and society. To avoid double counting insurance payments, insurance disbursements are subtracted from these estimates. Separate estimates are made for internal and external costs. To avoid double-counting insurance costs in chapter 3.1, these cost estimates are calculated net of insurance discernments. Internal crash costs are assigned per passenger mile, while external risk is assigned to vehicle miles.¹¹³ Although rural driving has fewer crashes per mile, they tend to be more severe due to higher speeds, so rural and urban driving crash costs are considered equal.

It could be argued that crash rates for some types of driving, particularly commuting, should be calculated excluding alcohol-involved crashes (about 25% of crashes), since drunk commuting is uncommon. This would imply that, for example, commute trip reduction programs reduce external crash costs at a lower rate than programs that reduce all types of driving equally. However, convicted drunk drivers often argue that they need their drivers license for employment, so a commute trip reduction program may help reduce drunk driving by allowing courts to revoke more driving privileges.

¹¹³ For example, a vehicle carrying only a driver imposes only about 10% of the *internal* crash risk as a vehicle carrying ten people, but the *external* crash risk is considered the same for both.

Internal Crash Costs: Internal crash costs for most automobile occupants, including rideshare passengers, are estimated at \$0.083 per passenger mile, (calculated as the average of Miller 1994 (\$0.17/VMT) and the low range of Cambridge Systematics 2008 (\$0.27/VMT) for \$ 0.22/VMT¹¹⁴, times 75% internal costs, minus insurance disbursements of \$0.041, divided by 1.5 average passengers).¹¹⁵ Compact cars are estimated here to impose 10% higher internal crash costs than an average car. The California Energy Commission’s crash cost estimate of \$0.014 per passenger mile is used for buses and trolleys, 22% of which is internal, for a cost of 2007 \$0.004 per PMT.

Motorcycle crash costs estimated at (1996 dollars) \$1.50 to \$2.57 per mile reflect this mode’s high crash and injury rates. This results in part because motorcyclists tend to be risk taking young men who have a crash rate 3 times higher than average when driving any type of vehicle, so a lower cost estimate can be used to represent the crash costs normalized for an average driver.¹¹⁶ Motorcycle fatality rates have declined since the FHWA study was produced. For these reasons, a demographically average driver who currently rides a motorcycle is assumed here to have a crash cost 1/5th of the FHWA’s study’s estimate (about 1/3 of Ted Miller’s more recent estimate), equal to 1996 \$0.514. Even with this modification crash risk dominates motorcycle costs. Internal motorcycle crash costs are estimated to represent 85% of this cost (a higher ratio of internal costs since motorcycles are less likely to injure other road users) minus \$0.07 for insurance disbursements (twice that of cars) resulting in 1996 \$0.437 or 2007 \$0.577 per mile.

Bicycles and walkers are estimated to incur internal crash risk equal to that of automobile occupants. If this analysis were based on *total health risk*, taking into account the aerobic exercise benefits of these activities, bicycling and walking would incur lower or negative costs. Telework is not considered to incur any crash risk.

Estimate Internal Crash Costs (2007 U.S. Dollars per Passenger Mile)

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.083	0.083	0.083	0.083
Compact Car	0.092	0.092	0.092	0.092
Electric Car	0.083	0.083	0.083	0.083
Van/Light Truck	0.083	0.083	0.083	0.083
Rideshare Passenger	0.083	0.083	0.083	0.083
Diesel Bus	0.004	0.004	0.004	0.004
Electric Bus/Trolley	0.004	0.004	0.004	0.004
Motorcycle	0.577	0.577	0.577	0.577
Bicycle	0.083	0.083	0.083	0.083
Walk	0.083	0.083	0.083	0.083
Telework	0.000	0.000	0.000	0.000

¹¹⁴ Values adjusted to 2007 USD by CPI. See section 5.3.6 for details of studies.

¹¹⁵ Alan Pisarski (1992), *Travel Behavior Issues in the 90’s*, FHWA, (www.fhwa.dot.gov), 1992, p. 52.

¹¹⁶ NHTSA. *Traffic Safety Facts*, National Highway Traffic Safety Administration (www.nhtsa.dot.gov).

External Crash Risk: Based on the same sources as internal crash risk (above), external crash costs for average automobiles and vans are estimated at 25% of 22¢ per vehicle-mile total crash costs, or 5.5¢. Compact cars impose a slightly lower external risk, estimated here at 5% less than a standard car. Rideshare passengers impose no additional external cost. External bus and trolley crash costs representing 78% of 34¢ per VMT. Motorcycles are estimated to have external crash costs of 10.2¢ per mile, representing 15% of 68¢.

Pedestrians and bicyclists can impose external crash costs by crashing into other nonmotorized travelers (such as a cyclist hitting a pedestrian or another cyclist), by contributing to motor vehicle crashes when drivers swerve to avoid them, and due to external medical care costs from their injuries. However, the majority of damage costs resulting from crashes between nonmotorized travelers and motor vehicles are allocated to the motor vehicle, since motor vehicles are heavier and faster. Pedestrians and bicycles are estimated here to impose 5% the external crash cost of average automobiles.

Estimate External Crash Costs (2007 U.S. Dollars per Vehicle Mile)

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.055	0.055	0.055	0.055
Compact Car	0.053	0.053	0.053	0.053
Electric Car	0.055	0.055	0.055	0.055
Van	0.055	0.055	0.055	0.055
Rideshare Passenger	0.000	0.000	0.000	0.000
Diesel Bus	0.264	0.264	0.264	0.264
Electric Bus/Trolley	0.264	0.264	0.264	0.264
Motorcycle	0.102	0.102	0.102	0.102
Bicycle	0.003	0.003	0.003	0.003
Walk	0.003	0.003	0.003	0.003
Telework	0.000	0.000	0.000	0.000

Automobile Cost Range: Crash cost estimates range from \$0.01 to \$0.43 per automobile mile, with comprehensive estimates ranging from \$0.17 to \$0.43. However the lowest estimates only account for selected costs. 15% to 50% of these costs are considered external based on studies cited, with a value of 37% used. The Minimum value is 1/3 of the maximum comprehensive estimate.

	<u>Minimum</u>	<u>Maximum</u>
Internal	\$0.06	\$0.27
External	\$0.05	\$0.16

Active Transportation Health Benefits Range: The standard values in Land Transport NZ's Economic Evaluation Manual (EEM) is used as a mid-range value. This source assumes that half of the benefit is internal to the people who increase their activity level by walking or cycling, and half are external benefits to society such as hospital cost

savings. Given that these values comes from only one source, a minimum value of half the value and a maximum of double the value is used for sensitivity analysis.

Active Transportation Health Benefits¹¹⁷

		Internal	External	2007 USD/mile
	low	0.05	0.05	0.10
Cycling	mid	0.10	0.10	0.19
	high	0.19	0.19	0.38
	low	0.12	0.12	0.24
Walking	mid	0.24	0.24	0.48
	high	0.48	0.48	0.96

¹¹⁷ Land Transport New Zealand (2006 / 2005) *Economic Evaluation Manual (EEM) – volumes 1 & 2* (www.landtransport.govt.nz); at www.landtransport.govt.nz/funding/manuals.html (Active transportation health benefits data is found in Volume 2, section 3.8, p 3-22)

5.3.11 Information Resources

Information sources on vehicle crash costs and transport safety strategies are described below.

Mark Anielski (2001), *The Alberta GPI Accounts: Auto Crashes and Injuries*, Pembina Institute (www.pembina.org).

Lawrence Blincoe (1995), *Economic Cost of Motor Vehicle Crashes 1994*, NHTSA, USDOT (www.nhtsa.dot.gov).

Lawrence Blincoe, et al. (2002), *Economic Cost of Motor Vehicle Crashes 2000*, USDOT, Report Number DOT HS 809 446. NHTSA (www.nhtsa.gov); at <http://lhsc.lsu.edu/OutsideLinks/EconomicImpact-1.pdf>.

BTS (annual reports), *National Transportation Statistics*, Bureau of Transportation Statistics (www.bts.gov). Provides information on transport activities, including traffic crashes.

Mark Delucchi (1996), *Personal Nonmonetary Costs of Motor-Vehicle Use*, Report #4 in *Annualized Social Cost of Motor Vehicle Use in the United States*, UC Davis (www.its.ucdavis.edu).

Aaron S. Edlin and Pinar Karaca Mandic (2001), *The Accident Externality from Driving*, University of California, Berkeley (<http://berkeley.edu/>); at http://works.bepress.com/aaron_edlin/21.

EDRG (2007), *Monetary Valuation of Hard-to-Quantify Transportation Impacts: Valuing Environmental, Health/Safety & Economic Development Impacts*, NCHRP 8-36-61, National Cooperative Highway Research Program (www.trb.org/nchrp); at www.statewideplanning.org/_resources/63_NCHRP8-36-61.pdf.

Rune Elvik and Ulf Rydningen (2002), *Road Safety Measures: Inventory of Estimates of Effect*, Norwegian Institute of Transport Economics, (www.toi.no), #572/2001.

The *European Road Safety Observatory* (www.erso.eu) provides information on European road crash statistics and safety strategies.

ICF Consulting (2003), *Cost-Benefit Analysis of Road Safety Improvements*, European Union (www.europa.eu.int); at http://europa.eu.int/comm/transport/road/library/icf_final_report.pdf.

FHWA (2004), *Traffic Safety Information Systems in Europe and Australia*, National Cooperative Highway Research Program (NCHRP), Panel 20-36, Federal Highway Administration (www.fhwa.dot.gov), AASHTO and TRB (www.trb.org); at http://international.fhwa.dot.gov/tsis_04010/2004TSISReportWeb.pdf.

FHWA (2002), *Highway Economic Requirements System: Technical Report*, Federal Highway Administration, USDOT (www.fhwa.dot.gov); at <http://isddc.dot.gov/OLPFiles/FHWA/010945.pdf>.

Lawrence Frank, Sarah Kavage and Todd Litman (2006), *Promoting Public Health Through Smart Growth: Building Healthier Communities Through Transportation And Land Use Policies*, Smart Growth BC (www.smartgrowth.bc.ca); at www.vtpi.org/sgbc_health.pdf.

Global Road Safety Partnership (www.grsproadsafety.org) is an international organization working to improve road safety in developing and transition countries. Provides international traffic crash data.

GRSP (2003), *Estimating Crash Costs*, Global Road Safety Partnership (www.grsproadsafety.org).

Paul F. Hanley (2004), *Using Crash Costs in Safety Analysis*, Public Policy Center, University of Iowa (<http://ppc.uiowa.edu/dnn4/PublicPolicybrCenter/tabid/36/Default.aspx>); at <http://ppc.uiowa.edu/dnn4/Publications/UsingCrashCostsinSafetyAnalysis/tabid/75/Default.aspx>

Markus Maibach et al. (2000), *External Cost of Transport: Accident, Environmental and Congestion Costs in Western Europe*. INFRAS Zurich / IWW University of Karlsruhe (www.infras.ch)

International Road Traffic and Accident Database, (www.oecd.org/document/53/0,2340,en_2649_34351_2002165_1_1_1_1,00.html) provides international crash data.

G. Jacobs (1995), *Costing Road Accidents In Developing Countries*, Overseas Unit, Transport and Road Research Laboratory (www.transport-links.org).

G. Jacobs, A. Aeron-Thomas and A. Astrop (2000), *Estimating Global Road Fatalities*, Overseas Unit, Transport and Road Research Laboratory (www.transport-links.org).

Michael Jones-Lee and Graham Loomes (2003), “Valuation of Safety,” *Handbook of Transport and the Environment*, Elsevier (www.elsevier.com), pp. 451-462.

Kara Maria Kockelman and Young-Jun Kweon (2002), “Driver Injury Severity: An Application of Ordered Probit Models,” *Accident Analysis and Prevention*, Vol. 34, No. 3 (www.elsevier.com/locate/inca/336), pp. 313-321; at www.ce.utexas.edu/prof/kockelman/home.html

Land Transport New Zealand (2006 / 2005) *Economic Evaluation Manual (EEM) – volumes 1 & 2* (www.landtransport.govt.nz); at www.landtransport.govt.nz/funding/manuals.html (Active transportation health benefits data is found in Volume 2, section 3.8, p 3-22)

Todd Litman (2003), “Integrating Public Health Objectives in Transportation Decision-Making,” *American Journal of Health Promotion*, Vol. 18, No. 1 (www.healthpromotionjournal.com), Sept./Oct. 2003, pp. 103-108; available at www.vtpi.org. Also see Todd Litman (2006), *If Health Matters, Integrating Public Health Objectives in Transportation Planning*, VTPI; at www.vtpi.org/health.pdf

Todd Litman and Steven Fitzroy (2008), *Safe Travels: Evaluating Mobility Management Traffic Safety Benefits*, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/safetrav.pdf.

David S. Loughran, Seth A. Seabury (2007), *Estimating the Accident Risk of Older Drivers*. RAND Corporation (www.rand.org); at www.rand.org/pubs/technical_reports/TR450/

Gordon Lovegrove and Todd Litman (2008), *Macrolevel Collision Prediction Models to Evaluate Road Safety Effects of Mobility Management Strategies: New Empirical Tools to Promote Sustainable Development*, Transportation Research Board 87th Annual Meeting (www.trb.org); at www.vtpi.org/lovegrove_litman.pdf.

Ted R. Miller, Shelli B. Rossman & John Viner (1991) *The Cost of Highway Crashes*, Urban Institute (www.urban.org).

Christopher Murray (Ed) (1996), *Global Burden of Disease and Injury*, Harvard University School of Public Health (www.hsph.harvard.edu/organizations/bdu).

National Association of Forensic Economics (www.nafe.net) is a professional organization for litigation experts, which includes valuation of non-market impacts, such as injury costs.

National Highway Traffic Safety Administration (www.nhtsa.dot.gov) and the *National Center for Statistics and Analysis* (www.nhtsa.dot.gov/people/ncsa/ncsa.html) provides comprehensive information on traffic crashes and safety programs in the U.S.

NHTSA (2005), *Motor Vehicle Traffic As A Leading Cause of Death in the U.S., 2002 – A Demographic Study*, National Highway Traffic Safety Administration (www.nhtsa.dot.gov) ; at www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/Rpts/2005/809843.pdf

NSC (annual), *Estimating the Costs of Unintentional Injuries*, National Safety Council (www.nsc.org); at www.nsc.org/resources/issues/estcost.aspx

NZMT (2006), *The Social Cost Of Road Crashes And Injuries - June 2006 Update*, New Zealand Ministry of Transport (www.transport.govt.nz); at www.transport.govt.nz/assets/NewPDFs/NewFolder/Social-cost-June-2006-update.pdf.

OECD, *International Road Traffic and Accident Database*, Organization for Economic Cooperation and Development (www.oecd.org); at www.oecd.org/document/53/0,2340,en_2649_34351_2002165_1_1_1_1,00.html.

Yves Page (2001), “A Statistical Model to Compare Road Mortality in OECD Countries,” *Accident Analysis and Prevention*, Vol. 33 (www.elsevier.com/locate/aap), pp. 371-385.

Francesca Racioppi, et al. (2004), *Preventing Road Traffic Injury: A Public Health Perspective For Europe*, WHO, Regional Office for Europe (www.euro.who.int/document/E82659.pdf).

Safety Conscious Planning (www.fhwa.dot.gov/planning/SCP), is a U.S. Federal Highway Administration website on ways to better incorporate safety into transport planning.

TrafficSTATS (www.aaafoundation.org/trafficSTATS) provides an interactive tool for providing information on traffic risk (by vehicle-mile, vehicle-trip and minute of travel) for different transport modes, travel conditions, demographic groups and various other parameters. This project is a joint venture between Carnegie Mellon University and the AAA Foundation for Traffic Safety.

Transit Safety & Security Website (www.transit-safety.volpe.dot.gov).

Transport Canada (www.tc.gc.ca/roadsafety) provides Canadian traffic crash data.

Transportation Research Board (2006), *Guidelines for Analysis of Investments in Bicycle Facilities*, NCH Report 552. (www.trb.org); at http://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_552.pdf.

UNITE (www.its.leeds.ac.uk/projects/unite) involves transport cost accounting.

van Essen, et al (2004), *Marginal Costs of Infrastructure Use – Towards a Simplified Approach*, CE Delft (www.ce.nl).

Vehicle-Related Fatalities Website (www.ite.org/crashes/index.htm), Institute of Transportation Engineers. Provides information on traffic deaths and links to safety information.

Vermeulen, et al (2004), *The Price of Transport: Overview of the Social Costs of Transport*, CE Delft (www.ce.nl).

William Vickrey (1968), “Automobile Accidents, Tort Law, Externalities, and Insurance: An Economist’s Critique,” *Law and Contemporary Problems*, Vol. 33, pp. 464-487; at www.vtpi.org/vic_acc.pdf.

Kip Viscusi and Joseph Aldy (2003), *The Value of Statistical Life: A Critical Review of Market Estimates Throughout The World*, AEI-Brookings (www.reg-markets.org); at www.aei.brookings.org/publications/abstract.php?pid=305.

VTPI, *Online TDM Encyclopedia*, Victoria Transport Policy Institute, chapters:

“Health and Fitness,” (www.vtpi.org/tdm/tdm102.htm).

“Safety Evaluation,” (www.vtpi.org/tdm/tdm58.htm).

“Transportation Statistics,” (www.vtpi.org/tdm/tdm80.htm).

WHO (2000), Carlos Dora and Margaret Phillips (eds), *Transport, Environment and Health*, World Health Organization, European Series, No. 89 (www.euro.who.int/document/e72015.pdf).

WHO (2004), *World Report on Road Traffic Injury Prevention: Special Report for World Health Day on Road Safety*, World Health Organization (www.who.int/world-health-day/2004/en).

Anming Zhang, Anthony E. Boardman, David Gillen and W.G. Waters II (2005), *Towards Estimating the Social and Environmental Costs of Transportation in Canada*, Centre for Transportation Studies, University of British Columbia (www.sauder.ubc.ca/cts), for Transport Canada (www.tc.gc.ca/pol/en/aca/fci/menu.htm); available at the UBC Sauder School of Business (www.sauder.ubc.ca).