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.

5.3.1 Index

5.3.2 Definitions

Public Health

Public health refers to the overall health and wellbeing of people in a community. Transportation affects public health in several ways, including traffic risk, pollution exposure, physical activity, affordability and physical access to medical services.[1][2]

Table 5.3.2-1 **Transportation Health Impacts**[3]

Health Enabling	Health Damaging
• Affordable access to health promoting services and activities (medical care, healthy food, recreation, schooling, employment, etc.). • Exercise, use of active transport modes such as walking and cycling.	• Traffic accidents • Air pollution exposure • Noise pollution exposure • Stress and anxiety • Constraints on active transport (walking and cycling) due to traffic • Financial costs burdens due to high transport costs

This table summarizes major categories of transportation health impacts.

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*. Traffic fatality data tends to be more available and reliable than for other crash types. For each motor vehicle crash death, eight persons are hospitalized, and 100 are treated and released from a clinic or hospital emergency room. [4] *Severity* refers to the degree of damage caused by a crash. *Vulnerable road users* refers to pedestrians, cyclists and motorcyclists. *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 5.3.2-2 lists major crash cost categories, including market and non-market costs.

---

[1] APHA (2010), *The Hidden Health Costs of Transportation: Backgrounder*, American Public Health Association (www.apha.org); at www.apha.org/advocacy/reports/reports.

[2] 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; at www.vtpi.org/health.pdf.

[3] J. Ball, et al. (2009), *Applying Health Impact Assessment To Land Transport Planning*, Research Report 375, New Zealand Transport Agency (www.ltsa.govt.nz); at www.ltsa.govt.nz/research/reports/375.pdf.

[4] Gwen Bergen, et al. (2014), "Vital Signs: Health Burden and Medical Costs of Nonfatal Injuries to Motor Vehicle Occupants — United States, 2012," *Morbidity and Mortality Weekly Report* (www.cdc.gov/mmwr), Vol. 63, No. 40, 10 October; at http://tinyurl.com/p633mn8.

Table 5.3.2-2 **Categories of Crash Costs**

Market	Non-Market
• Property damages to vehicles and other objects. • Lost income. • Emergency response services. • Medical treatment costs. • Crash prevention and protection expenditures.	• 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*, which emphasizes that such events are avoidable, as opposed to *accident*, which implies a random event. On the other hand, the term *accident* recognizes that all travel activity incurs risk, and most travelers make decisions that marginally increase these risks, such as driving relatively fast or looking away from the road to adjust a radio, and crashes may result from multiple risk factors, 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), but still be random accidents.

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

Physical Activity refers to physical exercise, which has a major effect on health. Inadequate physical activity, and resulting excessive body weight, contribute to various health problems including heart and vascular diseases, strokes, diabetes, hypertensive diseases, osteoporosis, joint and back problems, colon and breast cancers, and depression. More active transport appears to reduce long-term cognitive decline and dementia.[5] 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.[6] Even modest reductions in these illnesses can provide large health benefits.[7]

---

[5] K.I. Erickson, et al. (2010), "Physical Activity Predicts Grey Matter Volume In Late Adulthood: The Cardiovascular Health Study," *Neurology* (www.neurology.org); at www.neurology.org/cgi/content/abstract/WNL.0b013e3181f88359v1.

[6] 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).

[7] Nick Cavill and Adrian Davis (2007), *Cycling & Health: What's The Evidence?*, Cycling England, Department for Transport (www.dft.gov.uk); at www.dft.gov.uk/cyclingengland/site/wp-content/uploads/2009/01/cycling_and_health_full_report.pdf. David Rojas-Rueda, et al. (2011), "The Health Risks And Benefits Of Cycling In Urban Environments Compared With Car Use: Health Impact Assessment Study," *BMJ*, 343:d4521 (www.bmj.com); at www.bmj.com/content/343/bmj.d4521.full.

Active transport health benefits can be divided into direct, internal benefits to people who increase their physical activity, and external benefits to other members of society.[8] 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 may also benefit from higher productivity which is an *external benefit*.

Below are studies which examined active transport health impacts.

- Grabow, et al. estimated changes in health benefits and monetary costs if 50% of short summer trips were made by bicycle in typical Midwestern U.S. communities.[9] Across the study region of approximately 31 million people, mortality is projected to decline by approximately 1,100 annual deaths. The combined benefits of improved air quality and physical fitness are estimated to exceed $7 billion/year.

- A major study of 263,450 U.K. commuters by Celis-Morales, et al. (2017) found that, controlling for other factors, those who walk or bicycle have lower cardiovascular disease risk, and those who bicycle have lower cancer risk and lower all-cause mortality rates, indicating that on average cycle commuting provides net health benefits and increases longevity.[10]

- Rabl and de Nazelle estimate the health impacts caused by shifts from car to bicycling or walking, considering four effects: changes in physical fitness and ambient air pollution exposure to users, reduced pollution to other road users, and changes in accident risk.[11] Switching from driving to bicycling for a 5 km one-way commute 230 annual days provides physical activity health benefits worth 1,300 € annually and air emission reduction worth 30 €/yr. overall. The commuter that switches mode bears additional air pollution costs averaging 20 €/yr, but this impact depends on cycling conditions; cyclists' pollution exposure can be reduced if they ride separated from major roadways. Data from Paris and Amsterdam imply that any increase in accident risk is at least an order of magnitude smaller than physical activity health benefit.

- Cavill, Cope and Kennedy estimated that an integrated program that increases walking in British towns provides benefits worth £2.59 for each £1.00 spent,

---

8 Franco Sassi (2010), *Fit Not Fat: Obesity and the Economics of Prevention*, Organization for Economic Cooperation and Development (www.oecd-ilibrary.org); at http://www.oecd.org/document/31/0,3343,en_2649_33929_45999775_1_1_1_1,00.html.

9 Maggie L. Grabow, et al. (2011), "Air Quality and Exercise-Related Health Benefits from Reduced Car Travel in the Midwestern United States," *Environmental Health Perspectives*, (www.ehponline.org); http://dx.doi.org/10.1289/ehp.1103440.

10 Carlos A Celis-Morales, et al. (2017), "Association Between Active Commuting And Incident Cardiovascular Disease, Cancer, And Mortality: Prospective Cohort Study," *BMJ*, (https://doi.org/10.1136/bmj.j1456); at www.bmj.com/content/bmj/357/bmj.j1456.full.pdf.

11 Ari Rabl and Audrey de Nazelle (2012), "Benefits of Shift From Car to Active Transport," *Transport Policy*, Vol. 19, pp. 121-131; at www.citeulike.org/article/9904895.

considering just reduced mortality.[12] Including other benefits (reduced morbidity, congestion and pollution) would increase this value. The Department for Transport found even higher economic returns.[13]

- The *Health Economic Assessment Tool* (HEAT) *for Cycling and Walking* [14] provides methodologies for valuing active transportation benefits, including savings from avoided driving, increased happiness, and reductions in coronary heart disease, diabetes risk, congestion, pollution and crash risk.

- *Dynamic Modeling for Health Impact Assessment* (DYNAMO-HIA) also provides methodologies for valuing active transport health benefits of projects that change population physical activity, such as sidewalk and path construction.[15] Because it accounts for changing population health characteristics over time, it estimates somewhat lower (about a third) of the benefits at the HEAT Tool.

- A detailed review of active transport health benefits for the New Zealand Transport Agency calculated the following values for additional walking and cycling.

Walking and Cycling Per-Kilometre Benefits (2007 NZ$)[16]

	Per Walk-Kilometer	Per Bicycle-Kilometer
High	$5.01	$2.51
Medium	$4.27	$2.14
Low	$3.53	$1.77

- Guo and Gandavarapu (2010) conclude that the incremental costs of residential sidewalk construction are usually repaid by increased physical fitness and reduced vehicle air pollution health benefits.[17] They estimate that building sidewalks on all

[12] Nick Cavill, Andy Cope and Angela Kennedy (2009), *Valuing Increased Cycling in the Cycling Demonstration Towns*, Cycling England, Department for Transport (www.dft.gov.uk); at www.dft.gov.uk/cyclingengland/site/wp-content/uploads/2009/12/valuing-increased-cycling-in-the-cycling-demonstration-towns.pdf.

[13] DfT (2010), *Cycling Demonstration Towns – Development of Benefit-Cost Ratios* by the UK Department for Transport (www.dft.gov.uk); at www.dft.gov.uk/cyclingengland/site/wp-content/uploads/2010/02/091223-cdts-bcr-analysis-final-edit.pdf.

[14] WHO (2014), *Health Economic Assessment Tool for Cycling and Walking*, World Health Organization Region Office Europe (www.euro.who.int); at www.heatwalkingcycling.org.

[15] Theodore J. Mansfield and Jacqueline MacDonald Gibson (2015), "Health Impacts of Increased Physical Activity from Changes in Transportation Infrastructure: Quantitative Estimates for Three Communities," *BioMed Research International*, Vol. 2015 (http://dx.doi.org/10.1155/2015/812325); at www.hindawi.com/journals/bmri/2015/812325.

[16] J. A. Genter, et al. (2008), *Valuing The Health Benefits Of Active Transport Modes*, Research Report 359, NZ Transport Agency (www.nzta.govt.nz); at www.nzta.govt.nz/assets/resources/research/reports/359/docs/359.pdf.

[17] Jessica Y. Guo and Sasanka Gandavarapu (2010), "An Economic Evaluation Of Health-Promotive Built Environment Changes," *Preventive Medicine*, Vol. 50, Supplement 1, January, pp. S44-S49; at www.activelivingresearch.org/resourcesearch/journalspecialissues.

city streets would increase average daily active travel 0.097 miles and reduce automobile travel 1.142 vehicle-miles per capita, which increases 15 kcal/day per capita in average additional physical activity, predicted to offset weight gain in about 37% of residents, providing substantial healthcare cost savings.

- Gotschi estimated that Portland, Oregon's 40-year $138-605 million bicycle facility investments provide $388-594 million healthcare savings, $143-218 million fuel savings, and $7-12 billion in longevity value, resulting in positive net benefits.[18]

- Sælensminde estimates that each physically inactive person who starts bicycle commuting provides €3,000-4,000 annual economic benefits.[19]

- Meta-analysis by de Hartog, et al. indicates that people who shift from driving to bicycling enjoy substantial health benefits (3 to 14 month longevity gains), plus additional benefits from reduced air pollution and crash risk to other road users.[20]

---

[18] Thomas Gotschi (2011), "Costs and Benefits of Bicycling Investments in Portland, Oregon," *Journal of Physical Activity and Health*, Vol. 8, Supplement 1, pp. S49-S58; at http://tinyurl.com/4qt4mxj.
[19] Kjartan Sælensminde (2004), "Cost-Benefit Analysis of Walking and Cycling Track Networks Taking Into Account Insecurity, Health Effects and External Costs of Motor Vehicle Traffic," *Transportation Research A*, Vol. 38, No. 8 (www.elsevier.com/locate/tra), October, pp. 593-606.
[20] Jeroen Johan de Hartog, Hanna Boogaard, Hans Nijland and Gerard Hoek (2010), "Do The Health Benefits Of Cycling Outweigh The Risks?" *Environmental Health Perspectives*, doi:10.1289/ehp.0901747; http://ehp03.niehs.nih.gov/article/info%3Adoi%2F10.1289%2Fehp.0901747.

Discussion

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

5.3.3 Crashes

Traffic crashes are rare events as indicated in the table below. The average motorist has: less than one reported culpable (at fault) vehicle insurance claim per decade, mostly involving minor property damage; one culpable crash-related claim every 24 years; and one causality crash (causing injury or death) just once every 62 year. Even high-risk motorists (such as young males) drive most years without a reported culpable crash.

Table 5.3.3-1 **Vehicle Insurance Claim Frequencies in British Columbia** (1997)[21]

	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, total lifetime crash risk is significant and crashes can have catastrophic impacts, causing tens of thousands of deaths, millions of injuries and hundreds of billions in losses annually in the U.S. Traffic crashes are a leading cause of death among people in the prime of life.[22] The table below summarizes U.S. fatality data for various modes.

Table 5.3.3-2 **U.S. Transportation Fatalities** (1999)[23]

	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.

---

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

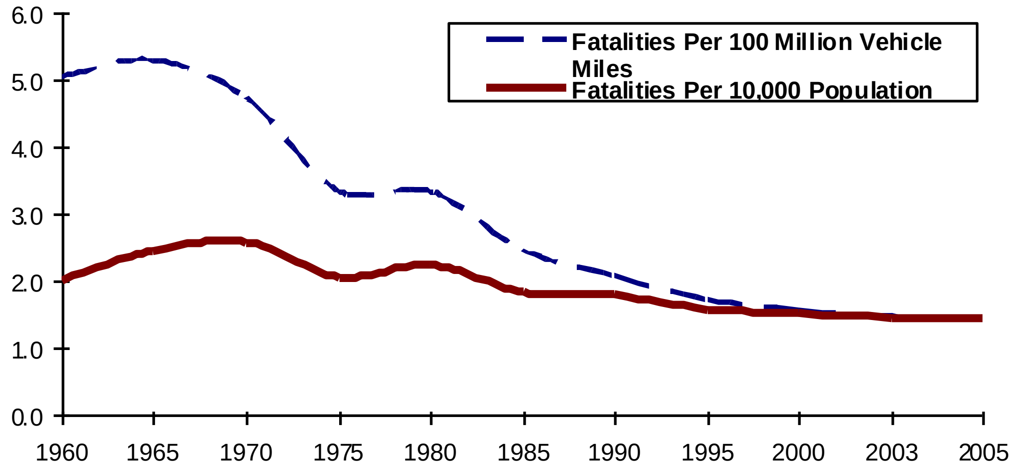
22 Christopher Murray Ed. (1996), *Global Burden of Disease and Injury*, Harvard University School of Public Health (www.hsph.harvard.edu).

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

Crash Evaluation Perspectives

Crashes can be measured in different ways which result in different conclusions about the risk of different modes and activities. 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 Rate**[24]



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 per vehicle-mile, passenger-mile, trip or hour of exposure.[25, 26] 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.

---

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

[25] 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

[26] Ian Savage (2013). "Comparing The Fatality Risks In The United States Transportation Across Modes And Over Time," *Research in Transportation Economics*, Vol. 43, No. 1, pp. 9-22; at http://faculty.wcas.northwestern.edu/~ipsavage/436-manuscript.pdf.

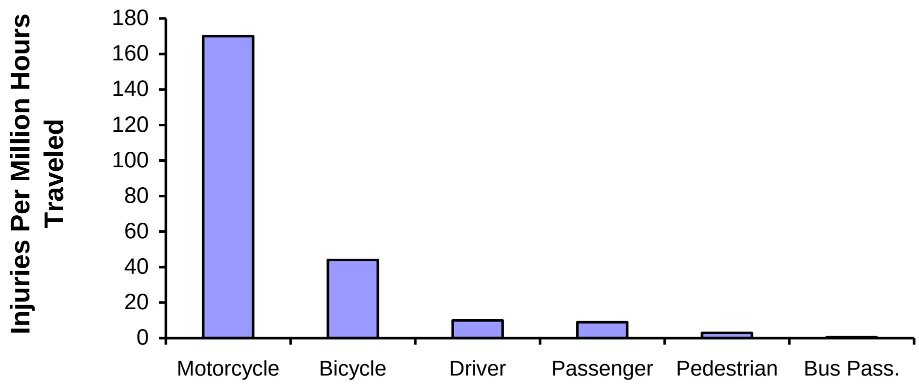
Table 5.3.3-3 **Fatalities per 100 Million Passengers in Britain** (1992)[27]

	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, walking and public transit.

Figure 5.3.3-2 **Time Based Injury Risk By Mode in New Zealand**[28]



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

Michael Sorensen and Marjan Mosslemi make a distinction between *objective* (actual) and *subjective* (perceived) risks.[29] For example, of 125 traffic safety strategies they evaluated, 78 were found to have positive effects on both subjective and objective safety, 25 have conflicting effects (improves objective safety but reduces perceived safety), and 20 have uncertain effects.

---

[27] Royal Society for Prevention of Crashes (1997), "Fasten Your Safety Belts," *The Economist* (www.economist.com), 11 Jan. 1997, p. 57.

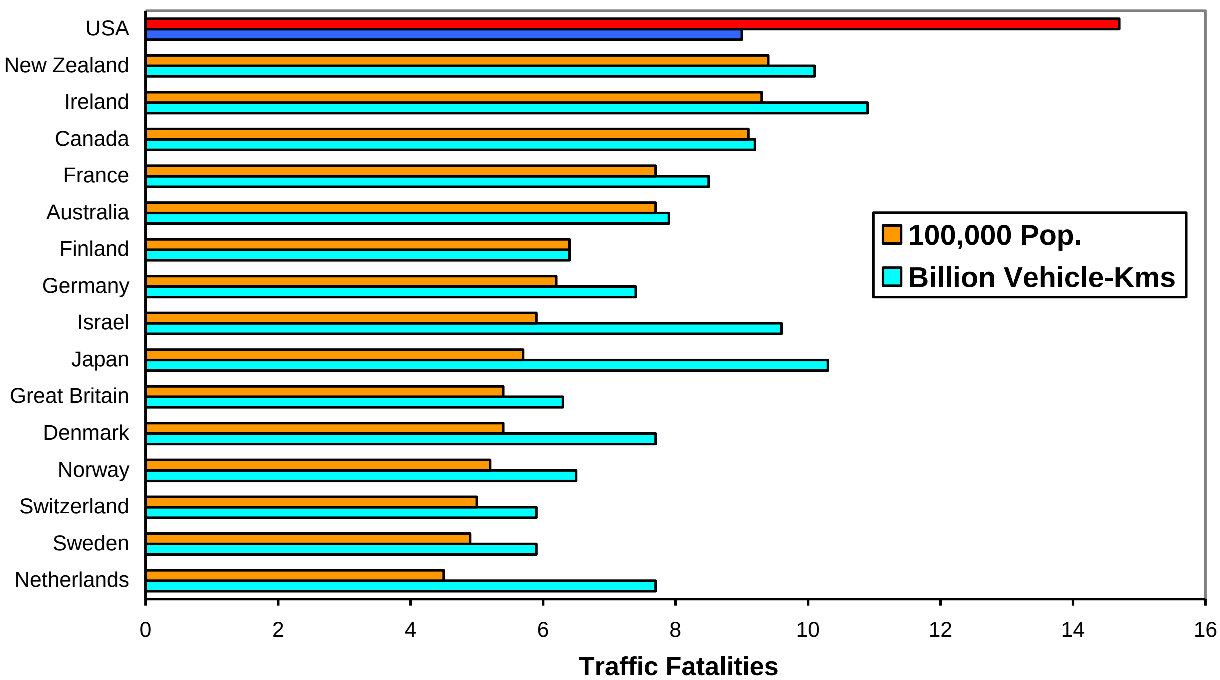
[28] NZMT (2006), *Risks of Different Modes*, New Zealand Ministry of Transport (www.transport.govt.nz); at www.transport.govt.nz/risk-modes.

[29] Michael Sorensen and Marjan Mosslemi (2009), *Subjective and Objective Safety - The Effect of Road Safety Measures on Subjective Safety Among Vulnerable Road Users*, Institute of Transport Economics (TØI) of the Norwegian Centre for Transport Research (www.toi.no); at www.toi.no/getfile.php/Publikasjoner/T%D8I%20rapporter/2009/1009-2009/1009-2009-nett.pdf.

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 sometimes exclude intentional injuries and deaths but suicides are difficult to identify. Some traffic deaths are under-recorded. 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.[30] 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%.[31]

Figure 5.3.3-3 **International Traffic Fatality Rates**[32]



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

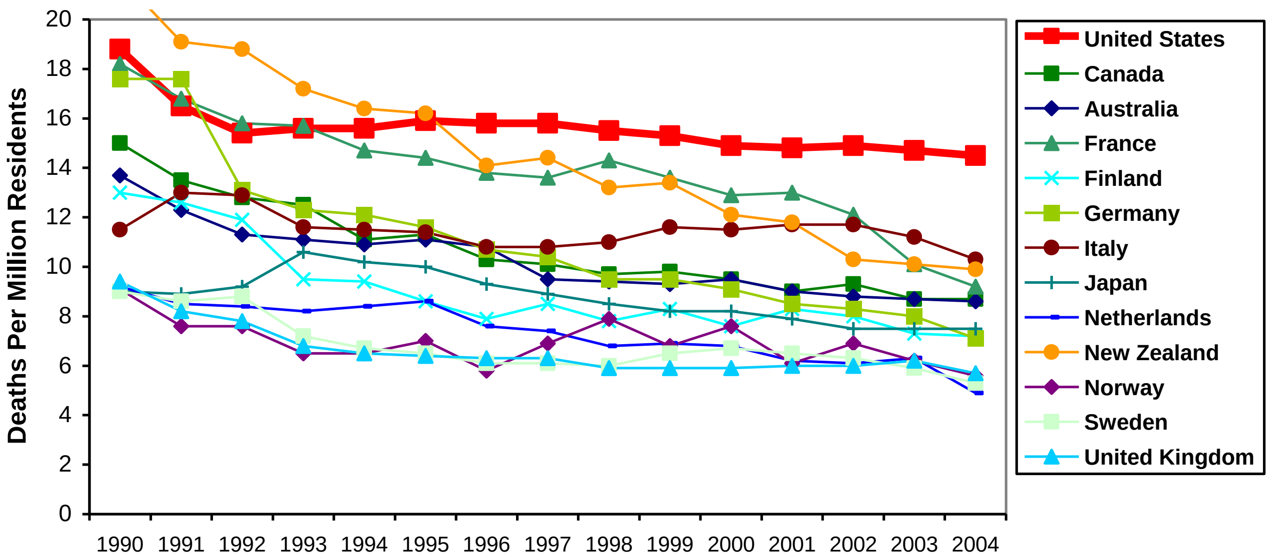
30 GRSF (2014), *Transport for Health: The Global Burden of Disease from Motorized Road Transport*, Global Road Safety Facility (www.worldbank.org/grsf) and the Institute for Health Metrics and Evaluation (www.healthmetricsandevaluation.org); at http://tinyurl.com/mfoxvt3.

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

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

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 5.3.3-3 and 5.3.3-4.

Figure 5.3.3-4 **Traffic Fatalities Per Million Residents in OECD Countries, 1990-2004.**[33]



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

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*.[34] 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*.[35] As a result, it can be difficult to ascertain the safety impacts of a particular strategy or program.

---

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

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

35 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.

Monetizing Crash Impacts

Numerous studies have monetized crash costs.[36] Several analytic techniques are used to monetize human health risks, as described in Chapter 4.[37] Human life is not a commodity: most people place virtually infinite value on their lives (they would not willingly die for any size payment), but many decisions involve tradeoffs between marginal changes in risk and money. For example, vehicle purchasers must sometimes decide whether to pay extra for safety equipment, such as air bags, that provide small safety gains. 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.

Willingness-to-pay usually results in lower values than willingness-to-accept due to budget constraints. For 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. Assuming that people have a right to live without injury from others, crash cost values should be based on *willingness-to-accept*, that is, the compensation a person would require before he or she would volunteer to experience such damages.[38]

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. Willingness to pay to avoid traffic fatalities is typically about five times greater than average crash fatality compensation.

---

[36] PIARC (2012), *State Of The Practice For Cost-Effectiveness Analysis, Cost-Benefit Analysis And Resource Allocation: Safer Road Operations*, World Road Association, (www.piarc.org); at www.piarc.org/en/order-library/17894-en-State%20of%20the%20practice%20for%20cost-effectiveness%20analysis,%20cost-benefit%20analysis%20and%20resource%20allocation.htm.

[37] Henrik Lindhjem, Ståle Navrud and Nils Axel Braathen (2010), *Valuing Lives Saved From Environmental, Transport And Health Policies: A Meta-Analysis Of Stated Preference Studies*, Environment Directorate, Organisation for Economic Co-operation and Development (www.oecd.org); at www.oecd.org/officialdocuments/displaydocumentpdf?cote=env/epoc/wpnep(2008)10/final&doclanguage=en.

[38] Fairness usually assumes that individuals have a right to be safe from losses caused by other people, indicating that *willingness-to-accept* is the appropriate measurement for damage compensation analysis.

Crash compensation rates can create conflicts between economic efficiency and equity objectives. Low compensation rates encourage people to be more cautious and discourage people who place relatively low value on their own health from intentionally causing injuires to obtain compensation. For example, although a small finger injury could cause some people (such as professional musicians) to lose hundreds of thousands of dollars in potential income (Django Reinhardt excepted), it would be poor public policy to compensate every lost pinky with $100,000, since some people might willingly sacrifice a finger for that much money. Full compensation may encourage risky behavior.

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.[39]

Two general perspectives are used in crash cost studies, reflecting the scope of impacts that are considered:[40]

- 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.

There is some variability in these cost values since analysis results depend on how research is conduced 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 $3,366,388.[41] 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.

---

39 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.

40 Ted Miller (1991), *The Costs of Highway Crashes*, FHWA (www.fhwa.dot.gov), Publ. FHWA-RD-055.

41 Lawrence Blincoe, et al. (2002), *Economic Cost of Motor Vehicle Crashes 2000*, USDOT, Pub. DOT HS 809 446. NHTSA (www.nhtsa.gov); at http://www.cita-vehicleinspection.org/Portals/cita/autofore_study/LinkedDocuments/literature/NHTSA%20the%20economic%20impact%20of%20motor%20vehicle%20crashes%202000%20USA%202002.pdf.

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 vehicle user), *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. 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. The table below indicates the distribution of various crash costs.

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 crash costs, since it imposes greater damages, regardless of which driver is legally responsible. Anderson and Auffhammer estimate that each additional 1,000 pounds of vehicle weight increases the fatality risk to other vehicle occupants by 40-50%, which they define as an external cost.[42]

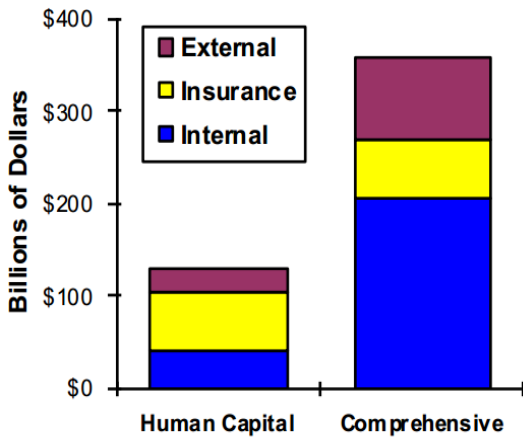
[42] Michael L. Anderson and Maximilian Auffhammer (2014), "Pounds That Kill: The External Costs of Vehicle Weight," *Review Of Economic Studies*, Vol. 81, No. 2, pp. 535-571; doi: 10.1093/restud/rdt035.

Elvik defines three types of crash externalities:[43]

- *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.[44] Jansson emphasizes external costs crashes imposed on unprotected road users (pedestrians, cyclists and motorcyclists), and uncompensated damage costs borne by society.[45] Other researchers also stress the costs motor vehicle risk impose on pedestrians and cyclists,[46] which tend to be undervalued because such crashes are under-recorded,[47] and because non-drivers experience reduced mobility and security. Figure 5.3-5. shows Miller's estimates of the magnitude and distribution of crash costs.

Figure 5.3.3-4 **Crash Cost Distribution**[48]



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.

---

43 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.

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

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

46 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).

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

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

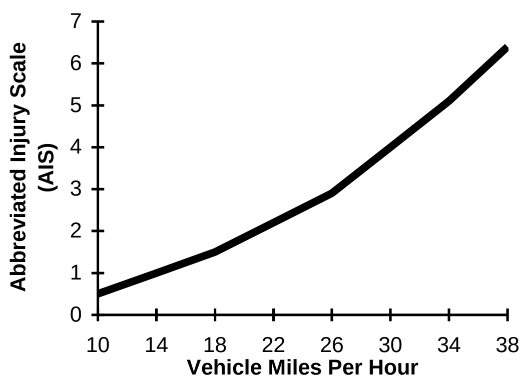
An efficient market requires that individuals bear the costs they impose, so crash costs should generally be evaluated at an individual level, reflecting the marginal costs imposed by each additional vehicle-mile driven. Because vehicle use imposes various types of external crash risk and uncompensated crash damages, optimal pricing of crash risk tends to be higher than indicated by insurance premiums.[49] For example, insurance premiums might average 5¢ per vehicle mile overall, but optimal pricing of crash costs might average 8¢ per mile, to reflect all marginal costs.

Roadway Conditions and Vehicle Speed

Many factors affect crash rates including roadway design, traffic speeds, traffic density, vehicle mix and speed variation.[50] 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*.[51] 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%.[52]

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.[53]

Figure 5.3.3-5 **Impact Speed Versus Pedestrian Injury**[54]



Pedestrian injury severity increases with vehicle impact speed.

---

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

[50] 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.

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

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

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

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

Traffic Congestion[55]

Crash rates tend to increase with traffic density,[56] 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.[57] 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.[58] Per mile c*rash* 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 Iowa**[59]

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
Total	*147*	*1.91*	*50*
Municipal			
Interstate	137	0.69	54
Primary	472	1.15	181
Secondary	558	0.79	174
Total	*469*	*0.88*	*157*

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*.[60] To the degree that roadway improvements increase traffic speeds and induce additional vehicle travel they may increase total crashes.[61]

---

[55] Paula Marchesini and Wendy Weijermars (2010), *The Relationship Between Road Safety And Congestion On Motorways: A Literature Review Of Potential Effects*, Report R-2010-12, SWOV Institute for Road Safety Research (www.swov.nl); at www.swov.nl/rapport/R-2010-12.pdf.

[56] 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.

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

[58] 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.

[59] 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.

[60] 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

[61] 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

Distance Traveled and Mobility Management

Analysis by Lovegrove and Litman (2008) using 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 suggest that vehicle kilometers traveled (VKT) and safety are so closely correlated that VKT can be used as a proxy for predicting the safety impacts of specific policies and programs.[62] Mobility management safety impacts are affected by the travel changes they cause. The results suggest the following:[63]

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.

Alternatives: A Risk Assessment Revisited," *Earthscan Reader on World Transport Policy & Practice*, Earthscan (www.earthscan.co.uk), pp. 247-258.

[62] 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 .

[63] 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.[64] A 240-kg increase in vehicle mass reduces fatalities an average of 10%, compared with a 43% reduction from seat belt use.[65] 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.[66] Rideshare passenger risk imposes 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	Increased risk to pedestrians due to quiet	"Road rage" risk	Replaces active transport
Large Vehicle (Van, Light Truck, SUV)	Reduced risk in multi-vehicle crashes. Higher rollover risk	High	"Road rage" risk	Replaces active transport
Rideshare Passenger	Depends on vehicle and driver	No incremental cost	Minimal	May replace active travel
Transit	Very low	Moderate	Assault risk	Usually involves walking
Motorcycle	Very high	Low risk to other road users; high medical costs	"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	Depends on whether teleworks exercise more or less than they otherwise would.

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

[64] 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).

[65] 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.

[66] 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.[67] 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.[68]

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.[69] Forkenbrock estimates external crash costs for heavy intercity trucks to average 0.59¢ per ton-mile.[70]

Road Conditions

The report, *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries* provides crash costs for various road types.[71]

Operator Factors

Various risk factors associated with the type of driver, cyclist or pedestrian that affect safety are described below.[72]

- 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.
- Talking on a telephone while driving significantly increases the risk of causing a crash.[73, 74]

---

67 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.

68 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.

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

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

71 Forrest Council, Eduard Zaloshnja, Ted Miller, Bhagwant Persaud (2005), *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries*, FHWA; at www.tfhrc.gov/safety/pubs/05051/index.htm.

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

73 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.

74 Peter D. Loeb and William A. Clarke (2009), "The Cell Phone Effect on Pedestrian Fatalities," *Transportation Research*, Vol. 45E, pp. 284–290.

Researchers Beck, Dellinger and O' Neil used vehicle travel data to calculate fatal and nonfatal traffic injury rates per 100 million person-trips by travel mode, sex, and age group. Fatal and non-fatal injury rates were highest for motorcyclists, pedestrians, and bicyclists. Table 5.3.3-7 summarizes their results.

Table 5.3.3-7 **U.S. Fatality Rate Per Trip by Transportation Modes, 1999-2003**[75]

	Automobile	Motorcycle	Walking	Cycling	Bus	Other	Total
Sex							
Male	12.4	551.2	20.3	27.6	0.4	35.1	14.6
Female	6.3	434.1	8.0	7.2	0.4	10.1	6.5
Age group	(Years)						
0–4	2.5		6.0				2.9
5–14	2.8		4.5	9.3		14.4	3.0
15–24	21.3		12.4	30.9		28.1	20.9
25–64	7.7	517.0	15.7	34.3	0.7	30.6	9.6
≥65	15.0		29.8	41.7	2.4	43.5	16.6
Total	9.2	536.6	13.7	21.0	0.4	28.4	10.4

Transport crash injury and fatality rates vary by mode, sex and age.

75 Laurie F. Beck, Ann M. Dellinger and Mary E. O'Neil (2010) "Motor Vehicle Crash Injury Rates by Mode of Travel, United States: Using Exposure-Based Methods to Quantify Differences," *American Journal of Epidemiology*, Vol. 166, No. 2, pp. 212-218; at http://aje.oxfordjournals.org/cgi/content/full/166/2/212#TBL2.

5.3.4 Active Transportation Health Benefits

Transport policy and planning decisions can have significant health impacts by affecting people's physical activity.[76] 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 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.[77] 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".[78] 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.[79]

Health experts recommend at least 150 weekly minutes (2.5 hours) of moderate exercise in intervals of ten-minutes or more.[80] Since people typically walk at 3-4 miles per hour and bicycle at 8-12 miles per hour, a combination of 7.5-10 walking miles or 20-30 cycling miles per week meets this target. These are minimum values so additional physical activity is desirable, but most people engage in other forms of exercise, so these are reasonable targets from a public health perspective. Overall, North Americans spend an average of about 6 daily minutes walking about 0.3 miles, which is about a quarter of public health target for basic physical fitness.[81]

More active transportation can provide many health benefits:[82]

- Physical inactivity contributes to numerous physical and mental health problems and is responsible for an estimated 200,000 deaths per year.
- Annual medical expenditures of physically able adults averaged $1,019 if they are regularly physically active and $1,349 if they reported being inactive.
- Annual healthcare costs increase $125 for people are overweight and $395 if they are obese.
- Nearly 80% of obese adults have diabetes, high blood cholesterol levels, high blood pressure, coronary artery disease or other ailments.

---

[76] VTPI (2008), "Health and Fitness," *Online TDM Encyclopedia*, (www.vtpi.org); at www.vtpi.org/tdm/tdm102.htm.
[77] 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
[78] 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.
[79] 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.
[80] CDC (2008), *Physical Activity Guidelines for Americans*, U.S. Center for Disease Control (www.cdc.gov); summary at www.cdc.gov/physicalactivity/everyone/guidelines/adults.html.
[81] Asha Weinstein and Paul Schimek (2005), *How Much Do Americans Walk? An Analysis of the 2001 NHTS*, #05-2246, Transportation Research Board 84th Annual Meeting (www.trb.org).
[82] ECU (2004), *Physical Activity Facts and Figures*, College of Health & Human Performance, East Carolina University (www.ecu.edu); at www.ecu.edu/picostcalc/pdf_file/FactsandFigures.pdf.

According to the National Institute of Diabetes and Digestive and Kidney Diseases, obese patient increase average medical costs in the following ways:[83]

- Medicare pays $95 more for an inpatient service, $693 more for a non-inpatient service, and $608 more for prescription drugs in comparison with normal-weight patients.
- Medicaid pays $213 more for an inpatient service,$175 more for a non-inpatient service, and $230 more for prescription drugs in comparison with normal-weight patients.
- Private insurers pay $443 more for an inpatient service, $398 more for a non-inpatient service, and $284 more for prescription drugs in comparison with normal-weight patients.

Health researchers estimated annual changes in health outcomes and monetary costs expected from reduced local air pollution emissions and improved public fitness if 50% of short trips were made by bicycle during summer months in typical Midwestern U.S. communities.[84] Across the study region of approximately 31.3 million people, mortality is projected to decline by approximately 1,100 annual deaths. The combined benefits of improved air quality and physical fitness are estimated to exceed $7 billion/year. These findings suggest that significant health and economic benefits are possible if bicycling replaces short car trips. Less auto dependence in urban areas would also improve health in downwind rural settings.

The World Health Organization's *Transport Environment and Health* report states that walk and bike commuting can provide significant health benefits which include:

- 50% reduction in coronary heart disease risk (a similar effect to not smoking)
- 50% reduction in adult diabetes risk
- 50% reduction in the risk of becoming obese
- 30% reduction in the risk of developing hypertension;
- 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
- prevention of falls in the elderly

---

83 E.A. Finkelstein, J.G. Trogdon, J.W. Cohen, W. Dietz (2009), "Annual Medical Spending Attributable To Obesity: Payer- And Service-Specific Estimates," *Health Affairs*, Vol. 28, No. 5, pp. w822–w831; cited in NIDDK (2010), *Statistics Related to Overweight and Obesity*, National Institute of Diabetes and Digestive and Kidney Diseases, National Institute of Health http://win.niddk.nih.gov/statistics/index.htm.

84 Maggie L. Grabow, et al. (2011), "Air Quality and Exercise-Related Health Benefits from Reduced Car Travel in the Midwestern United States," *Environmental Health Perspectives*, (www.ehponline.org); http://dx.doi.org/10.1289/ehp.1103440.

There is sometimes concern that the physical activity benefits of nonmotorized travel are offset by additional crash risk. Walking and cycling have relatively high casualty rates per mile or hour of travel, but the total incremental risk of shifts from driving to nonmotorized modes is generally small for these reasons:[85, 86, 87]

1. Nonmotorized travel imposes minimal risk to other road users.
2. High walking and cycling casualty rates partly reflect special risk factors by some user groups, including children and people with disabilities. A responsible adult who shifts from driving to nonmotorized travel and takes basic precautions such as observing traffic rules and wearing a helmet tends to have less than average risk.
3. Road users tend to be more cautious where they expect to encounter walkers and cyclists. As a result, per-mile casualty rates tend to decline as walking and cycling activity increases in a community, called the "safety in numbers" effect.
4. Increased walking and cycling may spur communities to implement nonmotorized safety improvements.
5. Nonmotorized trips tend to be shorter than motorized trips, reduing total per capita travel. A local walking trip often substitutes for a longer automobile trip and motorists tend to travel far more annual miles than non-motorists.
6. Some walking and cycling promotion programs include education and facility improvements that reduce per-mile bicycle crash rates.
7. The overall health benefits of increased walking and cycling are many times greater than the incremental risk, so people who regularly walk and bicycle tend to live longer than people who live sedentary lives.

Per capita collisions between motor vehicles and nonmotorized travelers declines with increased nonmotorized travel, indicating that shifts from driving to nonmotorized modes can reduce casualty rates.[88] For example, walking and cycling travel rates are high in Germany and the Netherlands and per capita traffic death rates relatively low.[89] Jacobsen calculates that the number of motorists colliding with pedestrians and cyclists increases at roughly 0.4 power of the number of people walking or cycling (doubling NMT travel in an area increases pedestrian/cycling injuries 32%), and the risk of being hit as a

---

[85] WHO (2014), *Health Economic Assessment Tool for Cycling and Walking*, World Health Organization Region Office Europe (www.euro.who.int); at http://tinyurl.com/3k8syj2.
[86] SQW (2007), *Valuing the Benefits of Cycling: A Report to Cycling England*, Cycling England, Department for Transport (www.dft.gov.uk); at www.dft.gov.uk/cyclingengland/site/wp-content/uploads/2008/08/valuing-the-benefits-of-cycling-full.pdf.
[87] Ari Rabl and Audrey de Nazelle (2012), "Benefits of Shift From Car to Active Transport," *Transport Policy*, Vol. 19, pp. 121-131; at www.citeulike.org/article/9904895.
[88] Nick Cavill, et al. (2007), *Economic Assessment Of Transport Infrastructure And Policies*, World Health Organization, Europe Region (www.euro.who.int); at www.euro.who.int/Document/E90944.pdf.
[89] Fietsberaad (2008), *Cycling in the Netherlands*, Ministry of Transport, Public Works and Water Management, The Netherland; at www.fietsberaad.nl/library/repository/bestanden/Cycling%20in%20the%20Netherlands%20VenW.pdf.

pedestrian declines 34% where walking and cycling double.[90] Robinson found similar results using Australian data: doubling bicycle travel in an area reduces per kilometer cycling crash rates about 34%.[91] The *Copenhagen Center for Prospective Population Studies* found a substantial decrease in the risk of death among those who spent 3 hours per week commuting to work by bicycle compared to those who did not commute by bicycle.[92] This and other studies indicate a linear or curvilinear dose-response relationship and there is no evidence of a threshold.

Most public transit trips involve walking or cycling links, so transit use tends to increase physical activity.[93] 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.[94] Efforts to encourage transit, reduce driving, and create transit oriented development often improve pedestrian and cycling conditions, which can further increase fitness and health. 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.[95]

---

90 Peter Jacobsen (2003), "Safety In Numbers: More Walkers and Bicyclists, Safer Walking and Bicycling." *Injury Prevention* (http://ip.bmjjournals.com), Vol. 9, pp. 205-209.

91 Dorothy Robinson (2005), "Safety in Numbers in Australia: More Walkers and Bicyclists, Safer Walking and Bicycling," *Health Promotion Journal of Australia*, Vol. 16, No. 1 (www.healthpromotion.org.au), April 2005, pp. 47-51.

92 L.B. Andersen, et al. (2000), "All-Cause Mortality Associated With Physical Activity During Leisure Time, Work, Sports and Cycling to Work," *Archives of Internal Medicine* Vo. 160, No. 11, pp. 1621-1628.

93 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).

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

95 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.

5.3.5 Personal Security

Personal Security refers to risk of intentional harm, including thefts and vandalism, assaults and terrorist attack. Certain transport activities are associated with security risks.[96] Motorists encounter threats such as "road rage" and vehicle thefts, while pedestrians, cyclists and transit passengers sometimes face threats of physical assault or theft.[97] It is difficult to quantify and compare these risks and since the most sensational incidents receive the most media coverage which can result in unrealistic sense of their magnitude.

The personal security risks of walking and cycling vary depending on demographics, location and time. Under most circumstances these modes are relatively safe. Shifting to these modes may sometimes increase risk, particularly where there are few other users, but strategies that increase the number of people walking and cycling on streets and paths tend to increase security in an area overall.[98] Although some urban neighborhoods have higher crime rates than suburban neighborhoods, this primarily reflects concentrated poverty. Infill by middle-class households and community design features that encourage social interactions among residents tend to reduce crime risk. Aggressive driving risk tends to be higher in more automobile dependent regions.[99] Overall, urban areas tend to have lower violent death rates (crashes and murders) than suburban locations.[100]

Public transportation is relatively safe overall. For example, in 2001 (the most recent available data) there were a total of 12 murders, 4,599 assaults and 12,302 property crimes committed against public transit patrons.[101] In comparison, during that year a total of 1,439,480 violent crimes were reported in the U.S. including 16,037 murders, approximately 40,000 carjackings (most involving a gun and about 15% resulting in injuries to victims),[102] approximately 909,023 aggravated assaults and 423,557 robberies, plus approximately 40,000 traffic deaths and 1,500 people seriously injured or killed in "roadrage" incidents.[103] Although some terrorism attacks have targeted public transport vehicles and stations this risk is overall relatively small.[104] Actual and perceived security

---

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

97 John Martin (2011), *The Incidence and Fear of Transit Crime: A Review of the Literature*, Centre for Public Safety, University of the Fraser Valley (www.ufv.ca); at www.ufv.ca/Assets/CCJR/Reports+and+Publications/Transit_Crime_2011.pdf.

98 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.

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

100 William Lucy (April 2002), *Danger in Exurbia: Outer Suburbs More Dangerous Than Cities*, University of Virginia (www.virginia.edu).

101 APTA (2003), *Public Transportation Fact Book*, American Public Transportation Association; at www.apta.com/resources/statistics/Documents/FactBook/APTA_2003_Fact_Book.pdf.

102 Patsy Klus (1999), *Carjackings in the United States, 1992-96*, Burea of Justice Statistics; at www.ojp.usdoj.gov/bjs/pub/pdf/cus96.pdf.

103 AAA (1997), *Aggressive Driving: Three Studies*, AAA Foundation for Traffic Safety; at www.aaafoundation.org/resources/index.cfm?button=agdrtext#Road%20Rage.

104 Todd Litman (2005), "Terrorism, Transit and Public Safety: Evaluating the Risks," *Journal of Public Transit*, Vol. 8, No. 4 (www.nctr.usf.edu/jpt/journal.htm), pp. 33-46.; at www.vtpi.org/transitrisk.pdf.

risks can be reduced with improved planning and programs, including community design that increases visibility of public spaces, community policing and Neighborhood Watch programs, special police patrols (including police on foot and bicycles), pedestrian escorts, and monitoring of transit vehicles and waiting areas.

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
Blincoe, et al. 2015	Motor Vehicles	$0.08-0.28	$0.08-0.27
NZTA	Benefit of increased walking and cycling	Cycling: NZ$1.40/km Walking: NZ$2.70/km	Cycling: $1.00 Walking: 1.93
Mansfield and Gibson 2015	Benefit of increased walking	Cycling: $0.30 Walking: $1.00	Cycling: $0.40 Walking: $1.25

*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

- Anderson and Auffhammer estimate that total U.S. accident externality costs total $136 billion annually, equivalent to a gas tax of $0.97 per gallon.[105]

- 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

[105] Michael L. Anderson and Maximilian Auffhammer (2014), "Pounds That Kill: The External Costs of Vehicle Weight," *Review Of Economic Studies*, Vol. 81, No. 2, pp. 535-571; doi: 10.1093/restud/rdt035.

VKT/VMT can sometimes be appropriately used as a proxy for predicting the safety impacts of policies and programs.[106]

- A comprehensive study for the National Highway Traffic Safety Administration estimates that in 2010 the U.S., motor vehicle crash costs totaled $242 billion in economic costs and $836 billion considering non-market values (pain and suffering from injuries and deaths), which averages 8¢ to 28¢ per mile driven.[107]

- 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.[108]

- A Swiss government study estimated that 1998 road traffic accident costs totaled 9.7 to 12.3 billion Swiss Francs (CHFs).[109] These include accident costs not recorded by the police. Of the social costs, around 1.5 billion remain as external costs which are not borne by the party causing the accident, but by the general public. External costs are mostly caused by the categories private car (723 million CHF), bicycle (257 million CHF) and motor assisted bicycle (176 million CHF). The social costs for rail accidents for 1998 amount to almost 132 million CHF (or 54 million CHF with low assessment of intangible costs). Of these around 14 million CHF are external costs.

- Elvik developed a Benefit-Cost model for evaluating several dozen traffic safety strategies.[110] He concluded 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)[111]

Study	Location	Passengers (passenger-km)	Freight (tonne-km)

[106] 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 .

[107] Lawrence J. Blincoe, Ted Miller, , Eduard Zaloshnja and BruceA. Lawrence (2015), *The Economic and Societal Impact of Motor Vehicle Crashes, 2010. (Revised)*, Report No. DOT HS 812 013, National Highway Traffic Safety Administration; at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013.

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

[109] Swiss ARE (2002), *Accident Costs of Road and Rail Traffic in Switzerland 1998* (*Unfallkosten im Strassen- und Schienenverkehr der Schweiz 1998*), Swiss Federal Office of Spatial Development (www.are.admin.ch).

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

[111] 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.

		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				

- 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.[112] He concludes that current official monetized crash values are lower than what consumers actually place on injury reduction.

- 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.**[113]

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%

This table compares fatalities per vehicle-kilometer for various modes. Fatalities per passenger-kilometer are much lower for higher occupancy vehicles such as buses.

- 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.[114] The table below shows his estimates of crash costs by vehicle class.

Table 5.3.6-4 **Miller's Estimate of Crash Costs**[115]

Mode	1994$ Per Vehicle Mile
Bus	$0.32
Light Truck	0.19

Mode	1994$ Per Vehicle Mile
Car (average)	$0.12
Car, Drunk Driver	$5.50

112 Marc Gaudry (2002), *Life, Limb and Bumper Trade-Offs Calculable from Road Accident Models*, Club of Jules Dupuit, University of Montreal (www.ajd.umontreal.ca).
113 Mayer Hillman and J. Adams (1995), "Safer Driving - Safer for Whom?," cited in *Urban Travel and Sustainable Development*, OECD (www.oecd.org), p. 54.
114 Ted Miller (1991), *The Costs of Highway Crashes*, Pub. FHWA-RD-055, FHWA (www.fhwa.dot.gov).
115 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.

Med/Hay Truck	0.13
Combination Truck	0.23

Car, Sober Driver	$0.06
Motorcycle	$1.50

- White finds that consider larger vehicles to be safer for occupants (internal benefits), but those vehicles pose greater danger to other road users (external costs).[116] 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.

North America

- 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.[117]

- 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 Transportation Institute's *Urban Mobility Study* congestion costs.[118] 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 comprensive cost of crashes and therefore reports higher values than sources which only cover selected or external costs.

- In 2008 the U.S. Department of Transportation established the economic value of a statistical human life to be $5.8 million, with a range of $3.2 million to $8.4 million for cost-benefit calculations of transportation projects that affect fatality rates.[119]

---

[116] 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.

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

[118] Cambridge Systematics (2008), *Crashes vs. Congestion - What's the Cost to Society?*, American Automobile Association (www.aaa.com); at http://newsroom.aaa.com/2008/03/crashes-vs-congestion-whats-the-cost-to-society.

[119] Tyler D. Duvall (2008), *Treatment of the Economic Value of a Statistical Life in Departmental Analyses*, Office of the Secretary of Transportation, U.S. Department of Transportation (http://ostpxweb.dot.gov/policy/reports/080205.htm).

- A study for Capital Region Intersection Safety Partnership (CRISP) committee developed a collision cost model that includes estimates of direct costs, human capital costs and willingness-to-pay to reduce damages from various types of crashes.[120] The results indicate that direct plus human capital costs average $1,819,800 for a fatality, $361,700 for a major injury, $47,200 for a minor injury and $11,400 for a property damage only crash. Willingness-to-pay costs average $ $5,416,200 for a fatality, $1,385,600 for a major injury, $30,600 for a minor injury and $11,400 for a property damage only crash.

- Edlin and Karaca-Mandic estimate auto accident externalities (more specifically insurance externalities) using panel data on state-average insurance premiums and loss costs.[121] 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 Values**[122]

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

- A study researchers estimated the monetary and nonmonetary quality-of-life costs of traffic crashes and major crimes in the State of Michigan. Monetary costs include costs of medical care, future earnings/lost wages, public services, adjudication and sanctioning, and property damage and loss. Quality-of-life costs are based on the current USDOT value of statistical life. The unit costs for crimes and crashes were computed in a comparable manner. These unit costs were applied to 2015 Michigan traffic crash and index crime incidence data to estimate dollar losses from traffic crashes and index crimes to the state and for each county within the state. Crash costs

---

[120] Paul de Leur (2010), *Collision Cost Study*, Capital Region Intersection Safety Partnership (www.drivetolive.ca); at www.drivetolive.ca/Downloads/Collision_Cost_Study_Final_Report_Feb_2010.pdf.
[121] Aaron S. Edlin and Pinar Karaca Mandic (2001), *The Accident Externality from Driving*, University of California, Berkeley (http://works.bepress.com/aaron_edlin/21).
[122] Paul F. Hanley (2005), *State Departments of Transportation's Use of Crash Costs in Safety Analysis*, TRB Annual Meeting (www.trb.org).

associated with alcohol-involved traffic crashes, crashes with unrestrained occupants of passenger cars, teen-driver-involved crashes, motorcycle crashes, and large truck crashes were also calculated. Findings indicate that Michigan index crimes in 2015 resulted in $2.0 billion in monetary costs and $8.0 billion in total (monetary and nonmonetary quality-of-life) costs. Overall traffic crashes in Michigan in 2015 resulted in $4.6 billion in monetary costs and $19.3 billion in total costs.[123]

- 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) [124]

	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

- Naumann, et al. Motor vehicle-related fatal and nonfatal injury costs exceeded $99 billion. Costs associated with motor vehicle occupant fatal and nonfatal injuries accounted for 71 percent ($70 billion) of all motor vehicle-related costs, followed by costs associated with motorcyclists ($12 billion), pedestrians ($10 billion), and pedalcyclists ($5 billion). [125]

- Parry calculates total and external accident costs, and the portion of these costs 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.

---

[123] Lidia P. Kostyniuk, et al. (2017), *Societal Costs of Traffic Crashes and Crime in Michigan: 2017 Update*, The University of Michigan Transportation Research Institute (http://deepblue.lib.umich.edu); at https://deepblue.lib.umich.edu/handle/2027.42/140723.

[124] NSC (2005), *Estimating the Costs of Unintentional Injuries*, National Safety Council (www.nsc.org).

[125] Rebecca B. Naumann, et al. (2010), "Incidence and Total Lifetime Costs of Motor Vehicle-Related Fatal and Nonfatal Injury by Road User Type, United States, 2005," *Traffic Injury Prevention*, Vol. 11, No. 4, August, pp. 353 – 360; at www.informaworld.com/smpp/section?content=a926084087&fulltext=713240928.

Table 5.3.6-7 **Crash Costs by Severity** (2004 U.S. dollars)[126]

	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
Total, Excluding Quality of Life Costs	*$177,706*	*$69,691*	*$21,543*	*$15,500*	*$2,983*
Quality of Life Costs	$3,000,000	$83,239	$19,560	$10,725	$464
Total, Including Quality of Life Costs	*$3,177,706*	*$152,930*	*$41,103*	*$26,225*	*$3,447*

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.

Table 5.3.6-8 **External Crash Costs** (2004 U.S. Cents Per Vehicle-Mile)[127]

	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¢
Total (cents/mile)	2.20¢	4.39¢	6.59¢
Total (billion dollars)	*$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*.

[126] 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.
[127] Parry, 2004, Table 6.

Table 5.3.6-9 **Estimated Highway External Crash Costs** (Cents Per Vehicle Mile)[128]

	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
All Vehicles	*9.52*	*3.09*	*1.68*	*3.98*	*1.26*	*0.76*	*6.12*	*1.97*	*1.11*

- 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.[129] 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).

- Miller, et al. estimate the costs of pedestrian and pedalcycle injuries in 2000 in the U.S. total $40 billion over the lifetimes of the injured. Most pedalcyclist injury costs and half of pedestrian injury costs do not involve motor vehicles. [130]

- A study sponsored by various Canadian government agencies estimates that in 2004, transportation accidents caused 3,067 deaths, 7,738 permanent partial disabilities, and 760 permanent complete disabilities, causing $2.1 billion in economic costs.[131]

- A National Highway Traffic Safety Administration study estimated Human Capital (which only reflects market costs such as property damage, medical treatment, and lost productivity) 2010 U.S. crash costs totaled $277 billion or $897 per capita, and $871 billion in total costs (including non-market costs).[132] Of these costs, approximately three-quarters are considered external to individual drivers involved in a crash. 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.

---

128 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

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

130 Ted R. Miller, et al. (2004), *Pedestrian And Pedalcyclist Injury Costs In The United States By Age And Injury Severity*, Annual Proceedings of the Association For The Advancement Of Automotive Medicine.

131 SMARTRISK (2009), *The Economic Burden of Injury in Canada*, (www.smartrisk.ca); at www.smartrisk.ca/index.php/burden.

132 Lawrence Blincoe, et al. (2014), *Economic And Societal Impact Of Motor Vehicle Crashes, 2010*, Report DOT HS 812 013, National Highway Traffic Safety Administration (www-nrd.nhtsa.dot.gov); at www-nrd.nhtsa.dot.gov/Pubs/812013.pdf.

Table 5.3.6-10 **NHTSA Estimate of Crash Costs** (2010)[133]

	PDO	**MAIS 0**	**MAIS 1**	**MAIS 2**	**MAIS 3**	**MAIS 4**	**MAIS 5**	**FATAL**
Injury Severity		None	Minor	Moderate	Serious	Severe	Critical	Fatal
Medical	$0	$0	$4,071	$25,933	$74,729	$201,152	$450,168	$11,317
Emergency Services	$28	$21	$89	$194	$416	$838	$855	$902
Market Productivity	$0	$0	$3,083	$41,342	$115,857	$185,008	$361,237	$1,156,859
HH Productivity	$60	$45	$1,027	$12,349	$35,658	$46,339	$110,232	$315,326
Insurance Administration	$191	$143	$4,588	$10,932	$25,772	$39,369	$81,707	$28,322
Workplace Costs	$62	$46	$341	$2,644	$5,776	$6,361	$11,091	$11,783
Legal Costs	$0	$0	$1,685	$8,017	$20,842	$37,358	$94,990	$106,488
Injury Subtotal	$341	$255	$14,883	$101,411	$279,050	$516,425	$1,110,280	$1,630,997
Congestion	$1,077	$760	$1,109	$1,197	$1,434	$1,511	$1,529	$5,720
Property Damage	$2,444	$1,828	$5,404	$5,778	$10,882	$16,328	$15,092	$11,212
Economic Subtotal	$3,862	$2,843	$21,396	$108,386	$291,366	$534,264	$1,126,901	$1,647,929
QALY (Nonmarket)	$0	$0	$24,382	$362,068	$864,455	$2,111,048	$4,970,847	$8,495,097
Total Comprehensive	$3,862	$2,843	$45,778	$470,453	$1,155,821	$2,645,312	$6,097,748	$10,143,026
Non-market/Total	0%	0%	53%	77%	75%	80%	82%	84%

PDO means "Property Damage Only." *MAIS* means maximum injury severity level by victims.

- 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)[134]

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.[135]

- 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.[136]

---

133 Blincoe, et al (2014), ibid. See original document for definitions.
134 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/techadvs/t75702.htm
135 Kara Maria Kockelman and Young-Jun Kweon (2002), "Driver Injury Severity," *Accident Analysis and Prevention*, Vol. 34, No. 3, pp. 313-321; at www.ce.utexas.edu/prof/kockelman/home.html.

- 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).[137] 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
Subtotal (Monetary Losses)	*1,088,592*	*46,025*	*15,793*	*9,067*	*1,672*
Quality of Life	2,093,660	113,992	25,566	10,647	244
Total	*3,182,252*	*160,016*	*41,359*	*19,714*	*1,916*

- 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)[138]

	All Vehicles	Passenger Cars	Light Trucks/Vans	Combination Trucks	Single Unit Trucks	Motor-cycles
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	$0215	$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.[139]

Australia and New Zealand

---

[136] NHI (1995), *Estimating the Impacts of Urban Transportation Alternatives, Participant's Notebook*, National Highway Institute, Federal Highway Admin. (www.fhwa.dot.gov), Course #15257, p. VI-28.
[137] 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).
[138] Jing-Shiarn Wang, Ronald R. Knipling and Lawrence J. Blincoe (1999), "Dimensions of Motor Vehicle Crash Risk, *Journal of Transportation and Statistics*, Vol. 2, No. 1 (www.bts.gov), May, pp. 19-43.
[139] 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

- The total cost of road crashes in Australia in 2006 has been conservatively estimated at approximately $17.9 billion (2006 Australian dollars), or 1.75 of GDP.[140] 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 estimated cost of a fatal crash was $2.67 million in 2006. The cost of a hospitalized injury crash was approximately $266,000 and the cost of a non-hospitalised injury crash was approximately $14,700. The average cost of a property damage-only crash was approximately $9,950.

- 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.[141] This included $1,241 million for fatalities, $1,353 million for serious injuries, $713 million for minor injuries and $800 million for property damages.

Europe and UK

- The UK Department of Transport Transport Analysis Guidance (TAG) program published values for prevention of casualties and accidents, with explanations of the basis of these estimates.[142] These include:
    - Human costs, based on WTP values, representing pain, grief and suffering to the casualty, relatives and friends, and, for fatal casualties, the intrinsic loss of enjoyment of life, excepting consumption of goods and services.
    - Loss of output due to injury. This is calculated as the present value of the expected loss of earnings plus any non-wage payments (national insurance contributions, etc.) paid by the employer. This includes the present value of consumption of goods and services that is lost as a result of injury accidents.
    - Hospital treatment and ambulance costs.

Tables 5.3.6-14 and 5.3.6-15 summarize these values in 2007 British Pounds.

Table 5.3.6-14 **Average Value Of Prevention Per Casualty By Severity** (UKDfT 2009)

Injury severity	Lost output	Human costs	Medical and Ambulance	Totals
Fatal. A death occurs within 30 days from causes arising out of the accident	£556,660	£1,080,760	£970	£1,638,390
Serious. Casualties require hospital treatment and	£21,830	£150,180	£13,230	£185,220

[140] BRTRE (2010), *Cost of Road Crashes in Australia 2006*, Report 118, Bureau of Transport and Regional Economics (www.btre.gov.au); at www.bitre.gov.au/publications/2010/files/report_118.pdf.
[141] NZMT (2006), *The Social Cost Of Road Crashes And Injuries - June 2006 Update*, New Zealand Ministry of Transport (www.transport.govt.nz).
[142] UKDfT (2009), *Transport Analysis Guidance*, UK Department for Transport (www.dft.gov.uk); at www.dft.gov.uk/webtag/webdocuments/3_Expert/4_Safety_Objective/pdf/3.4.1.pdf.

have lasting injuries but live at least 30 days.				
Slight. Injuries requiring no hospital treatment, or injury effects quickly subside.	£2,310	£10,990	£980	£14,280
Average, all casualties	*£11,200*	*£39,300*	*£2,350*	*£52,850*

This table summarizes the values used for transportation safety program economic evaluation by the UK Department of Transport.

Table 5.3.6-15 **Average Value Of Prevention Per Casualty By Road User Class** (UKDfT 2009)

Casualty Class	Value Per Avoided Casualty (2007 £)
Pedestrian	£84,690
Pedal cyclist	£53,630
Bus and coach occupants	£27,750
Goods vehicle occupants	£53,620
Car and taxi occupants	£40,980
Motorised two-wheeler rider and passengers	£100,050
All motor vehicle users	£48,020
Average, all road users	£52,850

These variations in value between classes of road user is due to differences in proportions of fatal, serious and slight casualties among each class of road user.

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

Table 5.3.6-16 **Crash Costs** (2003 Euros)[143]

	Lost Output	Human Costs	Medical Costs	Property Damage	Insuranc e 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 5.3.6-17 **Crash Costs to Unprotected Road Users by Jan Jansson** ($/km)[144]

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

143 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
144 Jan Jansson (1994), "Crash Externality Charges," *Journal of Transport Eco. and Policy* (www.bath.ac.uk/e-journals/jtep), Jan. 1994, p. 40.

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 5.3.6-18 **Marginal External Costs of Road Traffic Crashes in Great Britain**[145]

	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.[146]

- 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 5.3.6-18 **Crash Cost Values Used by U.K. COBA Model** (1994 Pounds)[147]

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

The UK Benefit-Cost model used standard values for various types of crashes.

[145] David Maddison, et al (1996), *The True Costs of Road Transport*, Earthscan (London), 1996, p. 133.
[146] 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.
[147] R. Vickerman (2000), "Evaluation Methodologies for Transport Projects in the United Kingdom," *Transport Policy*, Vol. 7, No. 1, January, pp. 7-12.

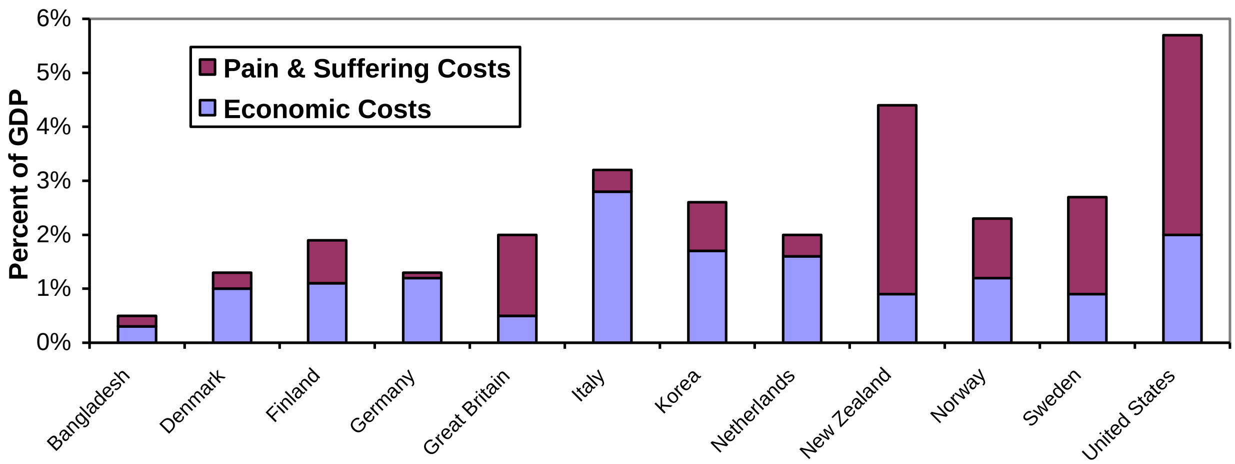
Global & International Comparisons

- Jacobs, Aeron-Thomas and Astrop describe recommended methodologies for calculating crash costs in developing countries.[148]

- The Asian Development Bank sponsored a series of studies that use standard analysis methods to estimate accident costs in ten Southeast Asian nations. [149]

- 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.[150]

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.

- The International Road Assessment Programme (www.irap.net) report, *The True Cost Of Road Crashes: Valuing Life And The Cost Of A Serious Injury*, reviews various countries' road crash injury and death monetized cost values as summarized in Table 5.3.6-18 to 6-20. It concludes that a default value of a statistical life (VSL) is 70 times average national GDP, with a 60 to 80 range for sensitivity analysis.

---

[148] G. Jacobs, A. Aeron-Thomas, and A. Astrop (2000), *Estimating Global Road Fatalities*, Report 445, Transport Research Laboratory (www.trl.co.uk); at www.esafetysupport.org/download/eSafety_Activities/Related_Studies_and_Reports/Estimating%20Global%20Road%20Fatalities%20report,%20TRL.pdf

[149] ADB (2005), *Accident Costing Reports*, Arrive Alive, Regional Road Safety Program, Asian Development Bank (www.adb.org); at www.adb.org/Documents/Reports/Arrive-Alive/Costing-Reports/default.asp.

[150] 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.

Table 5.3.6-18 **Value of Statical Life (VSL) in 2004 Dollars**[151]

Country	Value Statistical Life 2004 $	GDP/Capita 2004 $	Method
Australia	$1,304,135	$28,935	HC
Austria	$3,094,074	$35,871	WTP
Bangladesh	$71,066	$1,710	HC
Canada	$1,427,413	$29,851	HC
France	$1,252,083	$29,472	HC
Germany	$1,257,451	$28,953	HC
Iceland	$3,303,555	$44,679	HC+PGS
India	$147,403	$2,651	WTP
Indonesia	$92,433	$3,125	HC
Latvia	$1,042,743	$18,140	HC
Lithuania	$746531	$12,027	HC
Malaysia	$722,022	$9,513	WTP
Myanmar	$51,245	$1,545	HC
Netherlands	$1,944,026	$31,009	HC + PGS
New Zealand	$2,033,333	$25,024	WTP
Poland	$573,806	$14,984	HC
Singapore	$924,240	$25,034	HC
Sweden	$2,015,680	$32,394	WTP
Thailand	$222,056	$6,958	HC
UK	$2,292,157	$32,555	WTP
USA	$3,000,000	$36,311	WTP
Vietnam	$53,063	$2,475	HC

HC=Human Capital; WTP=Willingness-to-Pay; PGS=Pain-Grief-Suffering; VSI=Value of Serious Injury

Table 5.3.6-19 **Serious Injury Data for Developed Countries**

Country	Fatalities	Serious injuries	VSL	VSI	Ser. injuries/ fatalities	VSI/VSL %
Australia	1,634	22,000	$1,832,310	$397,000	13.4	22%
Austria	730	6,774	$2,676,374	$316,722	9.2	12%
Canada	2,936	17,830	$1,760,000		6.1	
France	5,318	39,811	$1,156,925	$124,987	7.5	11%
Germany	5,842	80,801	$1,161,885	$87,267	13.8	8%
Netherlands	987	11,018	$1,806,000		11.1	
New Zealand	405	3,950	$3,050,000	535,000	9.8	18%
Sweden	440	4,022	$18,383,000	3,280,000	9.1	18%
UK	3,221	31,130	$1,384,463	$155,563	9.7	11%
United States	42,815	356,000	$3,000,000	$464,663	8.3	15%

VSL= Value of statistical life; VSI = Value of statistical injury;

[151] IRAP (2009), *The True Cost Of Road Crashes: Valuing Life And The Cost Of A Serious Injury*, International Road Assessment Programme (www.irap.net); at www.irap.net/documents/pdf/iRAPValueoflifeseriousinjurypaper.pdf.

***Table 5.3.6-20* iRAP Economic Appraisal Model Values**[152]

	Lower	Central	Upper
Value of Fatality	60*GDP/Capita	70*GDP/Capita	80*GDP/Capita
Value of Serious Injury (VSI)	12*GDP/Capita (20%VSL)	17*GDP/Capita (25%VSL)	24*GDP/Capita (30%VSL)
Serious Injuries to Fatalities	8	10	12

This table summarizes the International Road Assessment Programme's recommendations for estimating the monetized value of traffic crash deaths and serious injuries.

- Kopits and Cropper estimate about 720,000 people die annually worldwide in traffic crashes and this will likely increase to about 1.2 million annual deaths in 2020.[153] They estimate that worldwide only about 50% of road injuries are reported, and there are about 100 injuries for each traffic fatality.

- A major study commissioned by the United Nations estimated that in Asian countries in 2013 road traffic accidents killed approximately 700,000 people, which imposed costs exceeding $735 billion, representing 1.8-4.2% of regional GDP.[154] A major portion of these traffic casualties and economic costs involve vulnerable road users (pedestrians, cyclists and motorcyclists) since those groups constitute a major portion of road traffic in those countries. The study uses these economic values to evaluate the economic justification for various road safety strategies.

- 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.[155] 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.[156] Table 5.3.6-21 summarized traffic risk cost studies by geographic region from a WHO report.

---

152 IRAP (2009).
153 Elizabeth Kopits and Maureen Cropper (2003), *Traffic Fatalities and Economic Growth*, World Bank Research Working Paper 3035 (www.worldbank.org).
154 Jac Wismans, et al. (2017), *Economics of Road Safety – What Does it Imply Under the 2030 Agenda for Sustainable Development?*, Tenth Regional EST Forum in Asia (www.uncrd.or.jp/?page=view&nr=984&type=13&menu=198); at http://bit.ly/2mW5BHV.
155 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.
156 WHO (2003), *The Injury Chartbook*, World Health Organization (www5.who.int).

Table 5.3.6-21 **Average Value Of Prevention Per Casualty By Road User Class**[157]

	Deaths and injuries	Deaths only	Injuries only	Other types of studies	Countries Reporting at least 1 study
African Region	15	2	0		17
Region Of The Americas	14	0	1		15
South-East Asia Region	6			1	7
Eastern Mediterranean Region	10	1		1	12
European Region	25	2			27
Western Pacific Region	11			2	13
All	*81*	*5*	*1*	*4*	*91*

- Mohan estimates India traffic crash costs total 1,772,183 million Rupees, more than 2% of GDP, similar to OECD countries.[158] Table 5.3.6-22 shows his summary of international cost estimates. Table 5.3.6-23 summarizes estimates for India.

Table 5.3.6-22 **International Crash Cost Estimates** (Mohan 2002)

Country	Year	Portion GDP	Value US$1997, mil	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, 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 Min. 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 Acc. 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

[157] WHO (2009), *Global Status Report On Road Safety: Time For Action*, World Health Organization (www.who.int); at www.who.int/violence_injury_prevention/road_safety_status/2009.
[158] 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 5.3.6-23 **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

Methodologies

- 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.[159]

- 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.[160]

- van Essen, et al, describe various method that can be used to calculate crash externalities.[161] 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. Estimate the relationship between traffic volume and accident frequency, and calculate the marginal increase of the expected number of accidents. For example a 5% traffic volume increase might increase accidents by 2%. Risk elasticities can be calculate from case-studies, literature review or planning models.
    3. Evaluate the monetary value of these changes by the means of willingness-to-pay/avoid method. This indicate the value of statistical life (VOSL). The marginal cost is the change in accident frequency multiplied by the costs per occurrence.

---

[159] LTNZ (2006), *Economic Evaluation Manual (EEM) – Volumes 1 & 2*, Land Transport New Zealand (www.landtransport.govt.nz); at www.landtransport.govt.nz/funding/manuals.html.
[160] FHWA (2002), *Highway Economic Requirements System: Technical Report*, Federal Highway Administration, (www.fhwa.dot.gov); at http://isddc.dot.gov/OLPFiles/FHWA/010945.pdf
[161] 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).

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

Various methods are used to quantify and monetize active transport health benefits.[162] The *Active Transport Quantification Tool* values various benefits, including reductions in crash risk, pollution emissions, coronary heart disease and diabetes risk.[163] The World Health Organization developed the *Health Economic Assessment Tool for Cycling (HEAT for Cycling)* tool that estimates the health effects of walking and cycling, and estimate the monetized value of increased active transport.[164, 165] Lindsay, Woodward and Macmillan used this model to calculate the economic benefits of shifting short urban trips from automobile to cycling in New Zealand.[166] They conclude that total health benefits significantly outweigh incremental road crash costs. The benefit/cost ratio increases as bicycle mode share increases (the ratio is 3:1 for 1% substitution and over 30:1 for 20% substitution) due to *safety in numbers* effects.

However, Mansfield and Gibson (2015) use a dynamic model that better accounts for the longevity benefits of increased physical activity, and conclude that the HEAT model significantly exaggerates health benefits by about three fold (i.e., actual health benefits are a third of what the HEAT model indicates).[167]

The City of Copenhagen has developed a standard cost-benefit analysis (CBA) methodology for evaluating cycle policies and projects which indicates that each additional kilometer cycled provides aveage health benefits (reduced medical and disability costs) valued at 1.11 Danish Kronor (DKK) to users and 2.91 DKK to society, plus 2.59 DKK worth of increased longevity.[168]

---

[162] Jane Powell, Anja Dalton, Christian Brand and David Ogilvie (2010), "The Role Of Walking And Cycling In Advancing Healthy And Sustainable Urban Areas," *Built Environment*, Vol. 36, No. 4, Dec. pp. 504-518; summary at www.atypon-link.com/ALEX/doi/abs/10.2148/benv.36.4.385.

[163] ICLEI (2007), *Active Transportation Quantification Tool*, Cities for Climate Protection, International Council for Local Environmental Initiatives (http://att.ccp.iclei.org); at http://att.ccp.iclei.org/more/about.

[164] WHO (2014), *Health Economic Assessment Tool for Cycling and Walking*, World Health Organization Region Office Europe (www.euro.who.int); at http://tinyurl.com/3k8syj2.

[165] Sonja Kahlmeier, Francesca Racioppi, Nick Cavill, Harry Rutter, and Pekka Oja (2010), "Health in All Policies" in Practice: Guidance and Tools to Quantifying the Health Effects of Cycling and Walking," *Journal of Physical Activity and Health*, Vol. 7, Supplement 1, pp. S120-S125; at www.euro.who.int/__data/assets/pdf_file/0009/97344/E93592.pdf.

[166] Graeme Lindsay, Alistair Woodward and Alex Macmillan (2008), *Effects On Health And The Environment Of Increasing The Proportion Of Short Urban Trips Made By Bicycle Instead Of Motor Vehicle*, School of Population Health, University of Auckland (www.fmhs.auckland.ac.nz).

[167] Theodore J., "Health Impacts of Increased Physical Activity from Changes in Transportation Infrastructure: Quantitative Estimates for Three Communities," *BioMed Research International*, Vol. 2015 (http://dx.doi.org/10.1155/2015/812325); at www.hindawi.com/journals/bmri/2015/812325.

[168] COWI (2009), *Economic Evaluation Of Cycle Projects - Methodology And Unit Prices*, *Samfundsøkonomiske Analyser Af Cykeltiltag - Metode Og Cases* and the accompanying note *Enhedsværdier for Cykeltrafik*, prepared by COWI for the City of Copenhagen (www.kk.dk/cyklernesby).

Guo and Gandavarapu identify various urban design factors that tend to increase walking and cycling, and reduce automobile travel.[169] They find that the provision of sidewalks significantly increases walking activity, and use a simple model to evaluate the cost effectiveness of neighborhood sidewalk construction based on health and air pollution reduction benefits. Boarnet, Greenwald and McMillan develop a framework for valuing the health benefits of urban design improvements that increase walking activity. The table below summarizes their estimated benefits of improving neighborhood walkability from 50 percentile to the 75 percentile (lower value) and 95 percentile (higher value), for a hypothetical 5,000 resident neighborhood.

Table 5.3.7-2 **Health Benefits From Various Neighborhood Walkability Changes**[170]

Neighborhood Walkability Changes	Total Benefits		Per Capita Benefits	
	Lower	Higher	Lower	Higher
Increase number of intersections within 1/2 mile	$2,255,107	$23,205,007	$451	$4,641
Increased retail employment density	$466,574	$18,331,955	$93	$3,666
Increased employment density	$155,525	$19,492,206	$31	$3,898
Increased population density	$1,555,247	$8,353,802	$311	$1,671
Distance from central business district	$4,510,215	$61,725,318	$902	$12,345

This table summarizes health benefits from neighborhood design changes that increase walking activity. "Lower" and "Higher" values indicate the ranges used for sensitivity analysis.

Stokes, MacDonald and Ridgeway developed a model to quantify public health cost savings from a new light rail transit system in Charlotte, NC.[171] Using estimates of future riders, the effects of public transit on physical activity (daily walking to and from the transit stations), and area obesity rates they estimate the potential yearly public health cost savings from this project. They estimate that the light rail system would provide cumulative public health cost savings of $12.6 million over nine years.

A Korea Transport Institute study found that commuters who switching from automobile to walking or cycling for eight weeks experienced significantly reduced blood pressure, improved lung capacity, and improved cholesterol counts.[172] It estimated that commuters who use active modes achieve annual health and fitness benefits averaging 2.2 million Korean Won (about $2,000). They found that incorporating these values into transport

---

[169] Jessica Y. Guo and Sasanka Gandavarapu (2010), "An Economic Evaluation Of Health-Promotive Built Environment Changes," *Preventive Medicine*, Vol. 50, Supplement 1, January 2010, pp. S44-S49; at www.activelivingresearch.org/resourcesearch/journalspecialissues.

[170] Marlon G. Boarnet, Michael Greenwald and Tracy E. McMillan (2008), "Walking, Urban Design, and Health: Toward a Cost-Benefit Analysis Framework," *Journal of Planning Education and Research*, Vol. 27, No. 3, pp. 341-358; at http://jpe.sagepub.com/cgi/content/abstract/27/3/341.

[171] Robert J. Stokes, John MacDonald and Greg Ridgeway (2008), "Estimating The Effects Of Light Rail Transit On Health Care Costs," *Health & Place*, Volume 14, Issue 1, March, pp. 45-58.

[172] Hyangun Sung, Jihyung Park and Hyeja Kim (2009), "A Study on the Impact of the Green Transport Mode on Public Health Improvement," *KOTI World-Brief*, Vol. 1, No. 1, Korea Transport Institute (www.koti.re.kr), May, pp. 6-8; http://english.koti.re.kr/upload/eng_publication_regular/world-brief01.pdf.

evaluation significantly affected outcomes, resulting in higher values for policies and projects that increase walking and cycling by otherwise senentary people.

Table 5.3.7-3 summarizes various monetized estimates of active transport benefits from a study commissioned by *Cycling England* (www.dft.gov.uk/cyclingengland).

Table 5.3.7-3 **Active Transportation Health Benefits**[173]

	Annual Value Per Additional Cyclist	Notes
SQW calculations	£22 for 16 - 44 £235 for over 45	Inactive people achieving activity target (30 daily minutes, 5 times a week) from cycling.
National Heart Forum	£11.16 for 16 – 44 years £99.53 for 45 - 64 years £242.07 for 65 years and over £58.77 weighted average	Analysis assuming a "step" increase in physical activity associated with cycling e.g. sedentary people become lightly active, lightly active become moderately active etc.
DCMS Game Plan (2002)	Between £40.79 and £50.73 depending on scenario	Implied value from report results. Uses foregone earnings, not full welfare costs
Copenhagen Heart Study/ Rutter	£498	Based on all cyclists (not just those becoming active) and all causes of mortality. Applied to UK data
DfT/Sustrans	£123	Number of deaths through inactivity and NHF values
TfL Business case	£88	As above but using London data
MACAW model	40 pence per kilometer	Assumed to be part of long term regular cycling

This table summarizes various monetized estimates of the health value of increased cycling.

The report, *Guidelines for Analysis of Investments in Bicycle Facilities* includes a summary of monetized health benefits from more active transportation, but the studies and estimates reflect different types of costs; for example, some only consider hospital charges while others include medical costs and lost productivity. None attempts to estimate the total of internal and external benefits. The values are not adjusted for inflation. The estimates range from $19 to $1,175 annual per capita; and the guideline simply uses the median value of $128 per person year.

173 SQW (2007), *Valuing the Benefits of Cycling: A Report to Cycling England*, Cycling England, Department for Transport (www.dft.gov.uk); at www.dft.gov.uk/cyclingengland/site/wp-content/uploads/2008/08/valuing-the-benefits-of-cycling-full.pdf.

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 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 some crash costs are external (not borne directly by the individual road user that causes them), and that vehicle insurance does not accurately reflect each motorists' insurance costs, crash cost pricing is inefficient. The health benefits of active transport raise equity and efficiency issues such as:

- Fairness of motorists inhibiting healthy 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 individuals and society. 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.[174] 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.

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/VMT[175], times 75% internal costs, minus insurance disbursements of $0.041, divided by 1.5 average passengers).[176] 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.[177] 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

---

[174] 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.
[175] Values adjusted to 2007 USD by CPI. See section 5.3.6 for details of studies.
[176] Alan Pisarski (1992), *Travel Behavior Issues in the 90's*, FHWA, (www.fhwa.dot.gov), p. 52.
[177] NHTSA. *Traffic Safety Facts*, National Highway Traffic Safety Administration (www.nhtsa.dot.gov).

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

External Crash Risk: Based on the same souces 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.

	Minimum	Maximum
Internal	$0.06	$0.27
External	$0.05	$0.16

5.3.11 Information Resources

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

APHA (2010), *The Hidden Health Costs of Transportation: Backgrounder*, American Public Health Association (www.apha.org); at www.apha.org/advocacy/reports/reports.

ARRB (2009), *Component Costs in Transport Projects to Ensure the Appropriate Valuing of Safety Effects*, Austroads (www.austroads.com.au); at www.onlinepublications.austroads.com.au/items/AP-T125-09.

J. Ball, M. Ward, L. Thornley, and R. Quigley (2009), *Applying Health Impact Assessment To Land Transport Planning*, Research Report 375, NZ Transport Agency (www.landtransport.govt.nz); at www.landtransport.govt.nz/research/reports/375.pdf.

Laurie F. Beck, Ann M. Dellinger and and Mary E. O'Neil (2007), "Motor Vehicle Crash Injury Rates by Mode of Travel, United States: Using Exposure-Based Methods to Quantify Differences," *American Journal of Epidemiology*, Vol. 166, No. 2; DOI: 10.1093/aje/kwm064; at http://aje.oxfordjournals.org/content/166/2/212.full.pdf.

Lawrence J. Blincoe, Ted Miller, Eduard Zaloshnja and Bruce Lawrence (2015), *The Economic and Societal Impact of Motor Vehicle Crashes, 2010. (Revised)*, Report No. DOT HS 812 013, National Highway Traffic Safety Administration; at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013.

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

Cambridge Systematics (2011), *Crashes vs. Congestion – What's the Cost to Society?*, American Automobile Association (www.aaa.com); at bit.ly/AAAcrashes2011.

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, TRB (www.trb.org); at http://tinyurl.com/l7y4ots.

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

Elliot Fishman, Jan Garrard, Ian Kar and Todd Litman (2012), *Cost and Health Benefits of Active Transport in Queensland: Research and Review*, Health Promotion Queensland (www.health.qld.gov.au); at http://tinyurl.com/k2kc5qd.

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

GRSF (2014), *Transport for Health: The Global Burden of Disease from Motorized Road Transport*, Global Road Safety Facility (www.worldbank.org/grsf) and the Institute for Health Metrics and Evaluation (www.healthmetricsandevaluation.org); at http://tinyurl.com/mfoxvt3.

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://ir.uiowa.edu/ppc_transportation/15.

International Road Traffic and Accident Database (www.internationaltransportforum.org/irtad/index.html) provides international crash data.

IRAP (2009), *The True Cost Of Road Crashes: Valuing Life And The Cost Of A Serious Injury*, International Road Assessment Programme (www.irap.net); at http://tinyurl.com/kcnf9ut.

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

G. Jocobs, A. Aeron-Thomas and A. Astrop (2000), *Estimating Global Road Fatalities*, Overseas Unit, Transport and Road Research Laboratory (www.transport-links.org); at www.factbook.net/EGRF_Regional_analyses_HMCs.htm.

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

Sonja Kahlmeier, Francesca Racioppi, Nick Cavill, Harry Rutter, and Pekka Oja (2010), "Health in All Policies" in Practice: Guidance and Tools to Quantifying the Health Effects of Cycling and Walking," *Journal of Physical Activity and Health*, Vol. 7, Supplement 1, pp. S120-S125.

Sonja Kahlmeier, et al. (2014), *Health Economic Assessment Tools (HEAT) tor Walking and For Cycling*, World Health Organization (www.heatwalkingcycling.org).

Lidia P. Kostyniuk, et al. (2017), *Societal Costs of Traffic Crashes and Crime in Michigan: 2017 Update*, The University of Michigan Transportation Research Institute (http://deepblue.lib.umich.edu); at https://deepblue.lib.umich.edu/handle/2027.42/140723.

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

Henrik Lindhjem, Ståle Navrud and Nils Axel Braathen (2010), *Valuing Lives Saved From Environmental, Transport And Health Policies: A Meta-Analysis Of Stated Preference Studies*, Environment Directorate, Organisation for Economic Co-operation and Development (www.oecd.org); at http://tinyurl.com/n4bgf76.

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; at www.vtpi.org/health.pdf.

Todd Litman (2005), *Terrorism, Transit and Public Safety: Evaluating the Risks*, VTPI (www.vtpi.org); at www.vtpi.org/transitrisk.pdf.

Todd Litman (2010), *Evaluating Public Transportation Health Benefits*, American Public Transportation Association (www.apta.com); at www.vtpi.org/tran_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.

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 Annual Meeting (www.trb.org); at www.vtpi.org/lovegrove_litman.pdf .

LTNZ (2010), *Economic Evaluation Manual (EEM) – Volumes 1 & 2*, Land Transport New Zealand (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).

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

Theodore J. Mansfield and Jacqueline MacDonald Gibson (2015), "Health Impacts of Increased Physical Activity from Changes in Transportation Infrastructure: Quantitative Estimates for Three Communities," *BioMed Research International*, Vol. 2015 (http://dx.doi.org/10.1155/2015/812325); at www.hindawi.com/journals/bmri/2015/812325.

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.

Cliff Naude, Dimitris Tsolakis, Fiona Tan and Tariro Makwasha (2015), *Social Costs of Road Crashes in Australia: The Case for Willingness-to-pay Values for Road Safety*, Austroads (www.austroads.com.au); at www.onlinepublications.austroads.com.au/items/AP-R438-15.

Rebecca B. Naumann, et al. (2010), "Incidence and Total Lifetime Costs of Motor Vehicle-Related Fatal and Nonfatal Injury by Road User Type, United States, 2005," *Traffic Injury Prevention*, Vol. 11, No. 4, August, pp. 353 – 360; at www.informaworld.com/smpp/section?content=a926084087&fulltext=713240928.

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

NHTSA (annual), *Traffic Safety Facts: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*, National Center for

Statistics and Analysis, National Highway Traffic Safety Administration (www.nhtsa.gov); at www-nrd.nhtsa.dot.gov/Pubs/812032.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.

NZTA (2010), *Economic Evaluation Manual*, Volumes 1 and 2, New Zealand Transport Agency (www.nzta.govt.nz); at www.nzta.govt.nz/resources/economic-evaluation-manual/volume-1/index.html and www.nzta.govt.nz/resources/economic-evaluation-manual/volume-2/docs/eem2-july-2010.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.

PIARC (2012), *State Of The Practice For Cost-Effectiveness Analysis, Cost-Benefit Analysis And Resource Allocation: Safer Road Operations*, World Road Association, (www.piarc.org); at http://tinyurl.com/kvgwpnv.

SMARTRISK (2009), *The Economic Burden of Injury in Canada*, (www.smartrisk.ca); at www.smartrisk.ca/index.php/burden.

Ian Savage (2013). "Comparing The Fatality Risks In The United States Transportation Across Modes And Over Time," *Research in Transportation Economics*, Vol. 43, No. 1, pp. 9-22; at http://faculty.wcas.northwestern.edu/~ipsavage/436-manuscript.pdf.

Niklas Sieber and Peter Bicker (2008), *Assessing Transportation Policy Impacts on the Internalization of Externalities of Transport*, Transport & Mobility Leuven for the European Commission; at www.tmleuven.be/project/refit/d3-3.pdf.

Nariida C. Smith, Daniel W. Veryard and Russell P. Kilvington (2009), *Relative Costs And Benefits Of Modal Transport Solutions*, Research Report 393, NZ Transport Agency (www.nzta.govt.nz); at www.nzta.govt.nz/resources/research/reports/393/docs/393.pdf.

Michael Sorensen and Marjan Mosslemi (2009), *Subjective and Objective Safety - The Effect of Road Safety Measures on Subjective Safety Among Vulnerable Road Users*, Institute of Transport Economics (TØI) of the Norwegian Centre for Transport Research (www.toi.no); at www.toi.no/getfile.php/Publikasjoner/T%D8I%20rapporter/2009/1009-2009/1009-2009-nett.pdf.

Hyangun Sung, Jihyung Park and Hyeja Kim (2009), "A Study on the Impact of the Green Transport Mode on Public Health Improvement," *KOTI World-Brief*, Vol. 1, No. 1, Korea Transport Institute (www.koti.re.kr), May 2009, pp. 6-8; http://english.koti.re.kr/upload/eng_publication_regular/world-brief01.pdf.

TC (2005-08), *The Full Cost Investigation of Transportation in Canada*, Transport Canada (www.tc.gc.ca/eng/policy/aca-fci-menu.htm); at www.tc.gc.ca/media/documents/policy/report-final.pdf.

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.

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

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

TRB (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.

TRISP (2005), "Valuation of Accident Reduction," *Economic Evaluation Notes*, UK Department for International Development and the World Bank (www.worldbank.org); at http://go.worldbank.org/ME49C4XOH0. Summarizes transport project evaluation methods suitable for developing country applications.

Polly Trottenberg (2011), *Treatment of the Economic Value of a Statistical Life in Departmental Analyses*, Office of the Secretary of Transportation, U.S. Department of Transportation (www.dot.gov); at www.dot.gov/sites/dot.gov/files/docs/Value_of_Life_Guidance_2011_Update_07-29-2011.pdf.

UKDfT (2009), *Transport Analysis Guidance*, UK Department for Transport (www.dft.gov.uk); at www.dft.gov.uk/webtag/webdocuments/3_Expert/4_Safety_Objective/pdf/3.4.1.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); at www.ce.nl/index.php?go=home.showPublicatie&id=181.

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.

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).

WHO (2008), *Health Economic Assessment Tool for Cycling* (HEAT for Cycling), World Health Organization Region Office Europe (www.euro.who.int); at www.euro.who.int/transport/policy/20070503_1.

WHO (2009), *Global Status Report On Road Safety: Time For Action*, World Health Organization (www.who.int); at www.who.int/violence_injury_prevention/road_safety_status/2009.

WHO (2014), *Health Economic Assessment Tool (HEAT) for Cycling and Walking*, World Health Organization (www.heatwalkingcycling.org).

Jac Wismans, et al. (2017), *Economics of Road Safety – What Does it Imply Under the 2030 Agenda for Sustainable Development?*, Tenth Regional EST Forum in Asia (www.uncrd.or.jp/?page=view&nr=984&type=13&menu=198); at http://bit.ly/2mW5BHV.

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); at www.bv.transports.gouv.qc.ca/mono/0965490.pdf.