5.13 Barrier Effect

This chapter describes the barrier effect (also called "severance"), which refers to delays that roads and traffic cause to nonmotorized travel. This indicates the benefits that can result from strategies that improve mobility for nonmotorized travel by reducing traffic impacts.

5.13.1 Chapter Index

5.13.2 Definitions

The *Barrier Effect* (also called *severance*) refers to delays, discomfort and lack of access that vehicle traffic imposes on nonmotorized modes (pedestrians and cyclists).[1] *Severance* usually focuses on the impacts of new or wider highways, while the barrier effect takes into account the impacts of vehicle traffic.

5.13.3 Discussion

Roads and vehicle traffic tend to create a barrier to pedestrian and cyclist travel.[2] The barrier effect is equivalent to traffic congestion costs (most traffic congestion cost estimates exclude impacts on nonmotorized travel). In addition to travel delays, vehicle traffic imposes crash risk and pollution on nonmotorized travelers. The barrier effect reflects a degradation of the nonmotorized travel environment. This is not to imply that drivers intentionally cause harm, but rather that such impacts are unavoidable when, heavy and hard vehicles traveling at high speed share space with vulnerable road users. Although it could be argued that impacts are symmetrical, because nonmotorized modes cause traffic delays to motorists, pedestrians and cyclists impose minimal risk, noise and dust on motorists so the costs they bear are inherently greater then the costs they impose.[3]

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[1] J. Stanley and A. Rattray (1978), "Social Severance" in *The Valuation of Social Cost*, Allen and Unwin; B.S. Hoyle and R.D. Knowles, *Modern Transport Geography*, Belhaven Press (London), p. 62.

[2] J.M. Clark and B.J. Hutton (1991), *The Appraisal of Community Severance*, Transport Research Laboratory (www.trl.co.uk), Report #135; Julian Hine and John Russel (1993), "Traffic Barriers and Pedestrian Crossing Behavior," *Journal of Transport Geography*, Vol. 1 No. 4, (www.elsevier.com/locate/jtrangeo), pp. 230-239.

[3] Damages resulting when motorists hit pedestrians and cyclists are considered accident costs, but not costs people bear when they change route or mode to avoid crash risk. The barrier effect represents such costs.

Barrier effect costs be illustrated by considering the impacts wider roads and increased motor vehicle traffic volumes and speeds have on local travel activity. Until the 1950s walking and bicycling was common for daily travel, but since then many of these trips shifted to automobile travel. Although many factors contribute to these shifts, an important one is the increased difficutly of walking and cycling on local streets due to higher traffic volumes and speeds. Narrow streets with lower traffic speeds and volumes are easy to cross, wider streets with higher traffic volumes and speeds cause discomfort and delay. For example, a survey of Austin, Texas residents investigated factors affecting their food store transport decisions.[4] The study found that busy roads create a significant barrier to walking which often causes shoppers to drive to nearby stores:

> One important factor besides distance is the quality of the connection between residential and commercial areas, in particular whether residents would have to cross a busy arterial to reach the store. In the focus groups, residents of several neighborhoods stressed this problem. Travis Heights residents, for example, like to walk to the shops in their neighborhood but cited South Congress Avenue as a dangerous obstacle and expressed their desire for more pedestrian-friendly elements such as a traffic island or a longer light at the crosswalks. Said one Travis Heights resident: "Getting back and forth across Congress is not a simple thing any more." Old West Austin residents, who do not have to cross an arterial to reach most local businesses but would have to cross an arterial to reach Whole Foods and several other popular destinations, expressed similar concerns: "You can't go across Lamar [Blvd.]. You can't go across Sixth Street. I mean you can, but you're taking your life into your hands." One resident's strategy for crossing the street is to "run like hell."
>
> Whether or not pedestrians feel comfortable walking around local shopping areas is also an important factor, suggesting that design and pedestrian infrastructure can influence the choice to walk. One Cherrywood resident said, "When you get there, there's no place for pedestrians. It's all parking lot." Another added, "I usually drive. The fact is, the only real concentration of retail we have is an automobile-oriented shopping center." A third complained that "there's no back way into it." Zilker residents said they don't feel safe walking along their commercial arterial, despite the sidewalk: "You've got the car speeding past on one side … and if you want to get to the business, you have to walk through the parking lot where the cars are milling around." The unattractive environment also makes a difference: "Lamar Boulevard is just an ugly street and it's really busy…it's really hard for people to walk," one Zilker resident said.

The barrier effect imposes indirect costs by reducing the viability of nonmotorized travel, which reduces accessibility for non-drivers, and causes shifts from nonmotorized to motorized travel which increases external costs such as traffic congestion, parking costs and pollution emissions. It tends to be inequitable because disadvantaged populations tend to bear a disproportionate share of this cost since they often depend heavily on nonmotorized transport. Studies indicate that many people would like to walk and bicycle more but are constrained, in part, by heavy roadway traffic.[5]

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[4] Susan L. Handy and Kelly J. Clifton (2001), "Local Shopping as a Strategy for Reducing Automobile Travel," *Transportation*, Vol. 28, No. 4, pp. 317–346.
[5] Robert Davis (1992), *Death in the Streets*, Leading Edge (North Yorkshire), 1992, p. 156.

Jacobsen, Racioppi and Rutter examine the impact of vehicle traffic on levels of walking and bicycling based on a comprehensive review of medical, public health, city planning, public administration and traffic engineering technical literature.[6] The analysis indicates that real and perceived danger and discomfort imposed by motor vehicle traffic discourages walking and bicycling activity. Observed evidence indicates an inverse correlation between traffic volumes and speeds and levels of walking and cycling. They conclude that reducing vehicle traffic speed and volume are likely to improve public health by increasing walking and bicycling activity.

These negative health impacts are measured by Jerrett, et al., who found a significant positive association between traffic density on neighboorhood streets and children's chances of being overweight in Southern California communities.[7] The impacts were particularly large for increased traffic exposure within 150 meters of children's homes. The effect translates into about a 5% increase in the average body mass index (BMI) attained at age 18. The researchers hypothesize two factors that explain this positive association between traffic density and increased body weight. First and most directly, traffic around the home may creates a sense of danger among parents and children that inhibits walking and cycling activity. Second, traffic air pollution reduces lung function and increases asthma, which reduces children's exercise capacity.

These impacts tend to be particularly large for the following groups and under the following circumstances:

- For children, who are less able to judge suitable crossing gaps.
- For people with physical disabilities, including most seniors, who tend to be slower crossing streets.
- Where major, high speed highways cross a village or town.
- In developing countries, where a major portion of residents rely on walking and cycling, and pedestrian accommodation (sidewalks, crosswalks, traffic speed enforcement) is often lacking.[8]

[6] Peter L. Jacobsen, F. Racioppi and H. Rutter (2009), "Who Owns The Roads? How Motorised Traffic Discourages Walking And Bicycling," *Injury Prevention*, Vol. 15, Issue 6, pp. 369-373; http://injuryprevention.bmj.com/content/15/6/369.full.html.
[7] Michael Jerret, et al. (2010), "Automobile Traffic Around The Home And Attained Body Mass Index: A Longitudinal Cohort Study Of Children Aged 10–18 Years," *Preventive Medicine*, Vol. 50, Supplement 1, January 2010, pp. S50-S58; at www.activelivingresearch.org/resourcesearch/journalspecialissues.
[8] Anurag Behar (2011) *India's Road-Building Rage: Symbolic Of Where India Is Going Is The Way We've Been Building Roads To Prosperity Which Are Also Our Roads To Perdition*, Other Sphere, Live Mint (www.livemint.com); at www.livemint.com/2011/01/26204034/India8217s-roadbuilding-ra.html?h=B#.

Evaluating Non-motorized Mobility

Various tools can be used to evaluate nonmotorized conditions. The *Pedestrian Road Safety Audit Guidelines and Prompt Lists* describes methods for evaluating walkability.[9] Multi-modal Level-of-Service (LOS) standards quantify walking and cycling conditions.[10]

Wellar developed the Walking Security Index which evaluates road crossing conditions, taking into account a wide range of variables that affect pedestrian safety, comfort, and convenience, as summarized in Table 1. This indicates that increased road width, traffic volumes, traffic speeds and higher truck volumes all reduce walking security ratings.

Table 1 **Walking Security Index Variables**[11]

Infrastructure	Vehicle Traffic	Pedestrian	Performance	Behavior
1. Number of lanes. 2. Speed 3. Grade (incline). 4. Turning lanes. 5. Curb cut at intersections. 6. Stop bar distance from crosswalk. 7. Sight lines	8. Peak vehicle volumes. 9. Vehicle types. 10. Trip purpose. 11. Turning movements.	12. Pedestrian volumes. 13. Pedestrian age.	14. Right-turn-on-red. 15. Signage. 16. Ice, snow and slush removal.	17. Pedestrian-vehicle collisions. 18. Pedestrian-vehicle conflicts. 19. Vehicle moving violations.

This table indicates factors to consider when evaluating pedestrian roadway crossing conditions.

[9] Dan Nabors, et al. (2007), *Pedestrian Road Safety Audit Guidelines and Prompt Lists*, Pedestrian and Bicycle Information Center (www.pedbikeinfo.org), Federal Highway Administration Office of Safety; at http://drusilla.hsrc.unc.edu/cms/downloads/PedRSA.reduced.pdf

[10] Richard Dowling, et al. (2008), *Multimodal Level Of Service Analysis For Urban Streets*, NCHRP Report 616, TRB (www.trb.org); at http://trb.org/news/blurb_detail.asp?id=9470; *User Guide* at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w128.pdf.

[11] Barry Wellar (1998), *Walking Security Index; Final Report*, Geography Department, University of Ottawa (www.geography.uottawa.ca).

Table 2 **Bicycle Level-of-Service**[12]

	Bicycle	Points
Facility (Max. value = 10)	Outside lane 3.66 m (12')	0
	Outside lane 3.66-4.27m (12-14')	5
	Outside lane >4.27m (14')	6
	Off-street/parallel alternative facility	4
Conflicts (Max. value = 10)	Driveways & sidestreets	1
	Barrier free	0.5
	No on-street parking	1
	Medians present	0.5
	Unrestricted sight distance	0.5
	Intersection Implementation	0.5
Speed Differential (Max. value = 4)	>48 KPH (>30 MPH)	0
	40-48 KPH (25-30 MPH)	1
	24-30 KPH (15-20 MPH)	2
Motor Vehicle LOS (Max. value = 2)	LOS = E, F, or 6+ travel lanes	0
	LOS = D, & < 6 travel lanes	1
	LOS = A, B, C, & < 6 travel lanes	2
Maintenance (Max. value = 2)	Major or frequent problems	-1
	Minor or infrequent problems	0
	No problems	2
TDM/Multi Modal (Max. value = 1)	No support	0
	Support exists	1

This table indicates how to quantify bicycle Level-of-Service (LOS). Higher traffic speeds and volumes, and wider roads with more traffic lanes reduce bicycling LOS.

Current transport planning practices tend to undervalue nonmotorized travel, and therefore barrier effect costs, because most travel surveys ignore or undercount shorter trips, non-work trips, off-peak trips, nonmotorized links of motorized trips, travel by children, and recreational travel.[13] For example, if a traveler takes 10 minutes to walk to a bus stop, rides on the bus for five minutes, and takes another five minute walk to their destination, this *walk-transit-walk* trip is often coded simply as a transit trip, even though the nonmotorized links take more time than the motorized link. Similarly, a 5 minute walk from a parking space to a destination is often ignored. There are usually far more nonmotorized trips than what conventional travel surveys and models recognize, and more potential demand (people who would walk or cycle if roadway conditions were suitable) than what occurs in most urban areas.

[12] Linda Dixon (1996), "Bicycle and Pedestrian Level-of-Service Performance Measures and Standards for Congestion Management Systems," *Transportation Research Record 1538*, TRB (www.trb.org), pp. 1-9; at www.enhancements.org/download/trb/1538-001.PDF.
[13] Todd Litman (2003), "Economic Value of Walkability," *Transportation Research Record 1828*, Transportation Research Board (www.trb.org), pp. 3-11; at www.vtpi.org/walkability.pdf.

Quantifying the Barrier Effect

Both the Swedish[14] and the Danish[15] roadway investment evaluation models incorporate methods for quantifying barrier effects on specific lengths of roadway. Both involve two steps. First, a barrier factor is calculated based on traffic volumes, average speed, share of trucks, number of pedestrian crossings, and length of roadway under study. Second, the demand for crossing is calculated (assuming no barrier existed) based on residential, commercial, recreation, and municipal destinations within walking and bicycling distance of the road. The Swedish model also adjusts the number of anticipated trips based on whether the road is in a city, suburb, or rural area, and the ages of local residents.

Russell and Hine recommend that the barrier effect be evaluated using "crossing ratios," which is the number of pedestrians who cross a road as a portion of total pedestrian flow along that segment.[16] This crossing ratio is considered inversely related to the barrier effect, although other factors may also influence such behavior. The barrier effect also applies to animals.[17]

5.13.4 Estimates

All values are in U.S. dollars unless otherwise indicated.

Summary Table

Table 5.13.4-1 **Barrier Effect Summary Table – Selected Values**

Publication	Costs	Cost Value	2007 USD
Bein (1997)	Per affected person	$1000 – 1500 Canadian*	$931 - 1397
Rintoul (1995)	Per vehicle km – urban highway	$0.087 Canadian***	$0.086
Sælensminde (1992)	Average vehicle mile	$0.01*	$0.015
Sælensminde (2002)	Shift from non-motorized to car, per non motorized km.	3.74-4.33 Norwegian Kroner (2002)	Per mile $0.54 - 0.62
	Per car km – urban	0.26 - .47	Per mile $0.04-0.07

*More detailed descriptions of these studies are found below, along with summaries of other studies. 2007 Values have been adjusted for inflation by Consumer Price Index. * Indicates that currency date is assumed to be the study date. ** Indicates result extrapolated from study data.*

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14 Swedish National Road Administration (1986), *Investment in Roads and Streets*, publication 1986:15E, (www.vv.se).
15 Danish Road Directorate (1992), *Evaluation of Highway Investment Projects* (undersogelse af storre hovedlandeveejsarbejder. Metode for effektberegninger og okonomisk vurdering), Danish Road Directorate (www.vejdirektoratet.dk).
16 John Russell and Julian Hine (1996), "Impact of Traffic on Pedestrian Behaviour; Measuring the Traffic Barrier," *Traffic Engineering and Control*, Vol. 37, No. 1 (www.tecmagazine.com), Jan. 1996, pp. 16-19.
17 H.D. van Bohemen (2004), *Ecological Engineering and Civil Engineering Works: A Practical Set Of Ecological Engineering Principles For Road Infrastructure And Coastal Management*, Delft University of Technology, (.library.tudelft.nl/ws/index.htm); at http://repository.tudelft.nl/file/80768/161791.

- Research by the BC Ministry of Transportation and Highways estimates that barrier effect costs average $1,000-1,500 (Canadian dollars) per affected person per year.[18]

- Rintoul calculates that a 5.3 kilometer stretch of major highway crossing through a medium size city imposes barrier effect costs of $2.4 million Canadian annually, or about 83¢ per capita each day.[19] The highway carries 13,600 average annual daily trips, so this cost averages about 8.7¢ Canadian per vehicle kilometer.

- A Danish publication estimates that the barrier effect represents 15% of roadway costs to be considered in benefit/cost analysis (total costs are 50% economic [travel time, accidents, VOC], 30% noise, 15% barrier effect, 5% air pollution).[20]

- The UK Department for Transport provides detailed guidance for evaluating severance impacts, which takes into account the degree that a roadway creates a barrier to pedestrian travel and the demand for such travel.[21]

- The *Bicycle Compatibility Index* includes a number of factors to evaluate how well a particular road accommodates cycling.[22] Increases road width, traffic volumes, traffic speeds, percentage large trucks, driveways, and parking turnover are all considered to reduce the mobility, safety and comfort of bicycle travel.

- The Swedish National Road and Transport Research Institute developed a method of calculating "encroachments costs," the physical encroachment by a road or a railway on an area of recreational, natural or cultural value. A typical case occurs when a road or a railway constitutes a barrier between a built-up area and nearby greenspace. Four cases have been studied. CVM (Contingent Valuation Method) is used to determine residents' willingness to pay (WTP) to replace the road or railroad with a tunnel.[23]

- The Pedestrian Environmental Factor (PEF) indicates that ease of crossing streets is a major factor in determining the amount of walking that occurs in an area.[24]

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[18] Dr. Peter Bein (1997), *Monetization of Environmental Impacts of Roads*, Planning Services Branch, B.C. Ministry of Transportation and Highways (www.gov.bc.ca/tran).

[19] Donald Rintoul (1995), *Social Cost of Transverse Barrier Effects*, Planning Services Branch, B.C. Ministry of Transportation and Highways (www.gov.bc.ca/tran).

[20] Klaus Gylvar and Leleur Steen (1983), *Assessment of Environmental Impacts in the Danish State Highway Priority Model*, Danish Road Directorate (www.vejdirektoratet.dk).

[21] DfT (2009), *Transport Analysis Guidance: 3.6.2: The Severance Sub-Objective*, Department for Transport (www.dft.gov.uk); at www.dft.gov.uk/webtag/documents/expert/unit3.6.2.php.

[22] David L. Harkey, Donald W. Reinfurt, J. Richard Stewart, Matthew Knuiman and Alex Sorton (1998), *The Bicycle Compatibility Index: A Level of Service Concept*, Federal Highway Administration, FHWA-RD-98-072 (www.fhwa.dot.gov); at .hsrc.unc.edu/research/pedbike/98095.

[23] Stefan Grudemo, Pernilla Ivehammar and Jessica Sandström (2002), *Calculation Model For Encroachment Costs Of Infrastructure Investments*, Swedish National Road and Transport Research Institute (www.vti.se); at www.vti.se/nordic/3-03mapp/pdf/page27.pdf.

[24] PBQD (1993), *The Pedestrian Environment*, 1000 Friends of Oregon (www.friends.org).

- Sælensminde estimates that the total cost of the barrier effect in Norway equals $112 per capita annually (averaging about 1¢ per vehicle mile), which is greater than the estimated cost of noise, and almost equal to the cost of air pollution.[25]

  - A cost-benefit analyses (CBAs) of walking- and cycling facilities in three Norwegian cities, taking account health impacts, vehicle air-pollution and noise, and parking costs estimates 3.74-4.33 Norwegian Kroner (46-54¢ U.S.) in lost benefits for each kilometer of urban travel shifted from nonmotorized modes to automobile due to the barrier effect.[26] This represents 3-6¢ per car-kilometer and 18-40¢ per bus-kilometer of travel. The report concludes, "*Barrier costs is a large external cost related to motorized traffic. It is therefore important to take the barrier cost into account, in the same way as other external costs, when for example the issue is to determine the 'right' level of car taxes or to evaluate different kinds of restrictions on car use.*"

- Tate evaluates various ways to evaluate the barrier effect, and proposes that this can be measured by asking parents whether they would be willing to allow a child to cross a street unaccompanied, under various road and traffic conditions.[27]

- Land Transport New Zealand includes community severance values in their project evaluation manual and recommends evaluating these effects based on pedestrian and cyclist travel times.[28]

5.13.5 Variability

As described in the Scandinavian literature, this impact depends on road width, traffic speeds and volumes, and the quality of pedestrian facilities.

5.13.6 Equity and Efficiency Issues

The barrier effect is an external cost, and so tends to be inequitable and inefficient. Since disadvantaged populations often depend heavily on nonmotorized transport, and so bear a disproportionate share of this cost, it tends to be vertically inequitable.

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[25] Kjartan Sælensminde (1992), *Environmental Costs Caused by Road Traffic in Urban Areas-Results from Previous Studies*, Institute for Transport Economics, Oslo (www.toi.no).

[26] Kjartan Sælensminde (2002), *Walking and Cycling Track Networks in Norwegian Cities: Cost-Benefit Analysis Including Health Effects and External Costs of Road Traffic*, Institute of Transport Economics, (www.toi.no); at www.toi.no/getfile.php/Publikasjoner/T%D8I%20rapporter/2002/567-2002/sum-567-02.pdf

[27] Fergus N. Tate (1997), *Social Severance*, Report No. 80, Transfund New Zealand (www.ltsa.govt.nz).

[28] Land Transport New Zealand (2006) *Economic Evaluation Manual (EEM) - volume 1* (www.landtransport.govt.nz); at .landtransport.govt.nz/funding/manuals.html.

5.13.7 Conclusions

The barrier effect is an external cost. It imposes direct costs on pedestrians and cyclists and indirect costs from reduced travel options and increased automobile use. Scandinavian and Canadian estimates indicate that the barrier effect is a significant cost. The Norwegian estimate of 1.5¢ per vehicle mile places this cost comparable to automobile noise, which seems reasonable and is used here to estimate automobile and motorcycle barrier costs. Transit vehicles are charged 2.5¢, based on barrier effect cost for trucks in Danish and Swedish models, but reduced to account for the extra pedestrian volumes associated with buses which provides safety in numbers at some road crossings.

Bicycling is estimated to incur 5% of an average automobile's barrier cost. Rideshare passengers, walking, and telecommuting incur no barrier costs. Although larger urban traffic volumes are balanced to some degree by higher speeds on rural roads, greater populations cause this cost to be highest in urban areas, especially during peak periods when traffic volumes are highest and the greatest demand exists for pedestrian and bicycle travel. For these reasons, the basic cost is applied to Urban Off-Peak driving and which is increased 50% for Urban Peak travel and decreased 50% for Rural driving.

Table 5.13.7-1 ***Estimate*** **- Barrier Effect (2007 U.S. Dollars per Vehicle Mile)**

Vehicle Class	Urban Peak	Urban Off-Peak	Rural	Average
Average Car	0.023	0.015	0.008	0.014
Compact Car	0.023	0.015	0.008	0.014
Electric Car	0.023	0.015	0.008	0.014
Van/Light Truck	0.023	0.015	0.008	0.014
Rideshare Passenger	0.000	0.000	0.000	0.000
Diesel Bus	0.038	0.025	0.013	0.023
Electric Bus/Trolley	0.038	0.025	0.013	0.023
Motorcycle	0.023	0.015	0.008	0.014
Bicycle	0.001	0.001	0.000	0.001
Walk	0.000	0.000	0.000	0.000
Telework	0.000	0.000	0.000	0.000

Automobile Cost Range

Because of limited quantified research of this cost in North America, the range is somewhat arbitrarily estimated at 50% and 200% of the estimate developed here.

Minimum	Maximum
$0.008	$0.03

5.13.8 Information Resources

Resources listed below provide information on evaluating impacts on nonmotorized travel.

ADONIS (1999), *Best Practice to Promote Cycling and Walking* and *How to Substitute Short Car Trips by Cycling and Walking*, European Union (www.europa.eu); at http://cordis.europa.eu/transport/src/adonisrep.htm.

Dan Burden (2003), *Level of Quality (LOQ) Guidelines*, Walkable Communities (www.walkable.org/library.htm); at www.tjpdc.org/transportation/walkability.asp.

J.M. Clark and B.J. Hutton (1991), *The Appraisal of Community Severance*, Report #135, Transport Research Laboratory (www.trl.co.uk).

DfT (2009), *Transport Analysis Guidance: 3.6.2: The Severance Sub-Objective*, Department for Transport (www.dft.gov.uk); at www.dft.gov.uk/webtag/documents/expert/unit3.6.2.php.

Richard Dowling, et al. (2008), *Multimodal Level Of Service Analysis For Urban Streets*, NCHRP Report 616, Transportation Research Board (www.trb.org); at http://trb.org/news/blurb_detail.asp?id=9470; *User Guide* at http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w128.pdf.

FDOT (2002), *Quality/Level of Service Handbook*, Florida Department of Transportation (www.dot.state.fl.us); at www.dot.state.fl.us/Planning/systems/sm/los/los_sw2.htm

Stefan Grudemo, Pernilla Ivehammar and Jessica Sandström (2002), *Calculation Model For Encroachment Costs Of Infrastructure Investments*, Swedish National Road and Transport Research Institute (www.vti.se); at www.vti.se/nordic/3-03mapp/pdf/page27.pdf

Susan Handy (2003), "Amenity and Severance," *Handbook of Transport and the Environment*, Elsevier (www.elsevier.com), pp. 117-140.

Harkey, et al (1998), *The Bicycle Compatibility Index: A Level of Service Concept*, FHWA, FHWA-RD-98-072 (www.fhwa.dot.gov); at http://safety.fhwa.dot.gov/tools/docs/bci.pdf

Peter L. Jacobsen, F. Racioppi and H. Rutter (2009), "Who Owns The Roads? How Motorised Traffic Discourages Walking And Bicycling," *Injury Prevention*, Vol. 15, Issue 6, pp. 369-373; http://injuryprevention.bmj.com/content/15/6/369.full.html.

Land Transport New Zealand (2006) *Economic Evaluation Manual (EEM) - Volume 1* (www.landtransport.govt.nz); at www.landtransport.govt.nz/funding/manuals.html.

Todd Litman (1994), "Bicycling and Transportation Demand Management," *Transportation Research Record 1441*, TRB (www.trb.org), pp. 134-140; now titled, *Quantifying the Benefits of Non-Motorized Transport for Achieving TDM Objectives*; at www.vtpi.org/nmt-tdm.pdf.

Anne Vernez Moudon (2001-2007), *Targeting Pedestrian Infrastructure Improvements*, Washington State DOT, WA-RD 519.1 (www.wsdot.wa.gov); at www.wsdot.wa.gov/Research/Reports/500/519.1.htm.

Dan Nabors, et al. (2007), *Pedestrian Road Safety Audit Guidelines and Prompt Lists*, Pedestrian and Bicycle Information Center (www.pedbikeinfo.org), Federal Highway Administration Office of Safety; at http://drusilla.hsrc.unc.edu/cms/downloads/PedRSA.reduced.pdf

NHI (1996), *Pedestrian and Bicyclist Safety and Accommodation; Participants Handbook*, National Highway Institute Course No. 38061, FHWA (www.fhwa.dot.gov).

Pedestrian and Bicycle Information Center (www.bicyclinginfo.org), NHTSA, and USDOT.

Kjartan Sælensminde (2002), *Walking and Cycling Track Networks in Norwegian Cities: Cost-Benefit Analysis Including Health Effects and External Costs of Road Traffic*, Institute of Transport Economics, Oslo (www.toi.no); at www.toi.no/getfile.php/Publikasjoner/T%D8I%20rapporter/2002/567-2002/sum-567-02.pdf.

Miles Tight (2005), *TRAN5230 Reading List*, Transport Studies Reading Lists, University of Leeds Library (http://library.leeds.ac.uk/); at http://lib5.leeds.ac.uk/rlists/transprt/tran5230.htm#Severance

H.D. van Bohemen (2004), *Ecological Engineering and Civil Engineering Works: A Practical Set Of Ecological Engineering Principles For Road Infrastructure And Coastal Management*, Delft University of Technology, Road and Hydraulic Engineering Institute, Directorate-General of Public Works and Water Management, Delft, Netherlands (www.library.tudelft.nl/ws/index.htm); at http://repository.tudelft.nl/file/80768/161791

VTPI (2008), "Evaluating Nonmotorized Transportation," (www.vtpi.org/tdm/tdm63.htm) and "Multi-Modal Level-Of-Service Indicators," (www.vtpi.org/tdm/tdm129.htm) *Online TDM Encyclopedia* (www.vtpi.org/tdm).