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 active modes (walking, bicycling and their variants). *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 walking and bicycling.[1] As described by Professor David Levinson,[2]

> "Roadways are designed to facilitate movement for cars while trapping pedestrians who want to cross the street. Cars don't literally eat pedestrians, but this environment certainly reduces the number of pedestrians, as people who would otherwise walk give up and join the motoring majority. We might say automobility eats walk mode share."

[1] 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.

[2] David Levinson (2021), *Networks as Connectors and Disconnectors*, The Transportist (https://transportist.org); at https://bit.ly/3NWAHeC.

The barrier effect results from the delay, risk, noise and air pollution exposure that motor vehicle travel imposes on walkers and bicyclists, which degrades nonmotorized travel conditions, reduces active travel, and causes travellers to shift to less preferred modes, which tends to increase user and external costs such as traffic congestion, road and parking facility costs and pollution emissions.[3] Studies indicate that many people would like to walk and bicycle more but are constrained, in part, by heavy roadway traffic.[4] It tends to be inequitable because disadvantaged populations tend to depend more on active modes and bear a disproportionate share of these cost. 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 speeds share space with vulnerable road users. Although it could be argued that impacts are symmetrical because active modes delay motorists, pedestrians and cyclists impose minimal risk, noise and dust, so the costs they bear are generally much greater then the costs they impose.

Barrier effect costs are illustrated by considering impacts on local travel activity. 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 found that busy roads create a significant barrier to walking which often causes shoppers to drive to nearby stores:[5]

> 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.”

Consider, for example, the effects of expanding a north-south street from four lanes (two traffic, two parking) designed for 20 mph speeds to six lanes (four traffic, two parking) designed for 40 mph with 2,000 peak-hour east-west trips. With the narrower,

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

[4] 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.

[5] 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.

slower street, 1,000 those trips were by active modes and 1,000 by automobile, but after the street is widened and traffic speeds increase, walking and bicycling trips decline to 500, causing 500 additional car trips, many of which are chauffeur trips that involve an empty backhaul, for example, a parent driving a child to school and returning home alone. This increases total vehicle traffic and congestion delay on the corridor. Barrier effect costs include all of these impacts:

- Delay, discomfort and risk to pedestrians and bicyclists from wider roads and increased vehicle traffic.
- Reduced mobility for non-drivers who forego some desired trips.
- Shifts from active to motorized trips, including empty backhauls of chauffeuring trips.
- The additional user costs and external costs (traffic and parking congestion, accident risk and pollution emissions) caused by this additional vehicle travel.

Urban freeways can impose particularly damaging barrier effects.[6] For example, in Pittsburgh, Pennsylvania, the construction of Interstate 579 devastated a Black community known as the Hill District. It displaced thousands of Black families and effectively cut off the District from the city's thriving downtown area. The District lost more than four hundred businesses and its population dropped from approximately fifty-four thousand in 1950 to 9,500 in 2013.[7]

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.[8] 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.

Jerrett, et al., found a significant positive association between neighbourhood street traffic density and children's chances of being overweight in Southern California.[9] The

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[6] Deborah N. Archer (2020), "White Men's Roads Through Black Men's Homes': Advancing Racial Equity Through Highway Reconstruction," *73 Vanderbilt Law Review 1259*, Public Law Research Paper No. 20-49; at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3539889.

[7] Sam Ross-Brown (30 Sept. 2016), "Transportation Secretary Foxx Moves to Heal Scars of Urban Renewal," *The American Prospect*; at https://perma.cc/G8Z3-NSPP.

[8] 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.

[9] 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.

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 create 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 children, who are less able to judge suitable crossing gaps.
- For people with physical disabilities, 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.[10]

[10] 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* describe methods for evaluating walkability.[11] Multi-modal Level-of-Service (LOS) standards quantify walking and cycling conditions.[12]

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**[13]

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.

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11 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

12 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.

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

Table 2 **Bicycle Level-of-Service**[14]

	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.[15] 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.

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[14] 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.

[15] 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[16] and the Danish[17] 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.[18] 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.[19]

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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16 Swedish National Road Administration (1986), *Investment in Roads and Streets*, publication 1986:15E, (www.vv.se).

17 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).

18 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.

19 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.

- Austroads estimates that the urban barrier effect averages $1.30 for cars, $0.50 for buses and $0.70 for train travel per 1,000 passenger-kilometers.[20]

- Research by the BC Ministry of Transportation and Highways estimated that barrier effect costs average $1,000-1,500 (Canadian dollars) per affected person per year.[21] 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.[22] The highway carries 13,600 average annual daily trips, so this cost averages about 8.7¢ Canadian per vehicle kilometer.

- 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.[23]

- The *Bicycle Compatibility Index* includes a number of factors to evaluate how well a particular road accommodates cycling.[24] 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.[25]

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[20] Caroline Evans, et al. (2015), *Updating Environmental Externalities Unit Values*, Austroads (www.austroads.com.au); at www.onlinepublications.austroads.com.au/items/AP-T285-14.

[21] 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).

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

[23] 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.

[24] David L. Harkey, et al. (1998), *The Bicycle Compatibility Index: A Level of Service Concept*, FHWA-RD-98-072, Federal Highway Administration, (www.fhwa.dot.gov); at .hsrc.unc.edu/research/pedbike/98095.

[25] 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.

- 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.[26]

- A cost-benefit analyses (CBAs) of walking- and cycling facilities in three Norwegian cities, taking account health impacts, noise, pollution 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.[27] This represents 3-6¢ per car-kilometer and 18-40¢ per bus-kilometer of travel. The report concludes, "*Barrier costs are 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.[28]

- 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.[29]

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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[26] Kjartan Sælensminde (1992), *Environmental Costs Caused by Road Traffic in Urban Areas-Results from Previous Studies*, Institute for Transport Economics, Oslo (www.toi.no).
[27] Kjartan Sælensminde (2002), *Walking and Cycling Track Networks in Norwegian Cities: Cost-Benefit Analysis Including Health Effects and External Costs*, Institute of Transport Economics, (www.toi.no).
[28] Fergus N. Tate (1997), *Social Severance,* Report No. 80, Transfund New Zealand (www.ltsa.govt.nz).
[29] Waka Kotahi (2021), *Monetised Benefits and Costs Manual*, New Zealand Transport Agency (www.nzta.govt.nz); at www.nzta.govt.nz/resources/monetised-benefits-and-costs-manual.

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 costs are significant. 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.

Steve Abley, Dave Smith and Stacy Rendall (2014), *Australasian Pedestrian Crossing Facility Selection Web Tool*, Austroads (www.austroads.com.au); at http://bit.ly/austroads_pedestrian.

Paulo Rui Anciaes, et al. (2016), "Urban Transport and Community Severance: Linking Research and Policy to Link People and Places," *Journal of Transport & Health*, Vol. 3/3, pp. 268–277 (doi.org/10.1016/j.jth.2016.07.006).

Paulo Rui Anciaes, Peter Jones and Jennifer S. Mindell (2016), "Community Severance: Where is it Found and at What Cost?" *Transport Reviews*, Vo. 36/3, Pages 293-317 (https://doi.org/10.1080/01441647.2015.1077286). Also see, *What is Community Severance?* blog (https://communityseverance.wordpress.com).

Deborah N. Archer (2020), "White Men's Roads Through Black Men's Homes': Advancing Racial Equity Through Highway Reconstruction," *73 Vanderbilt Law Review 1259*, Public Law Research Paper No. 20-49; at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3539889.

A. Bradbury, P. Tomlinson and A. Millington (2007), *Understanding the Evolution of Community Severance and its Consequences on Mobility and Social Cohesion Over the Past Century*, Association for European Transport Conference (https://trid.trb.org/view/855411).

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, TRB (www.trb.org); at https://bit.ly/3reAV6H; *User Guide* at https://bit.ly/3r5xLCh.

Caroline Evans, et al. (2015), *Updating Environmental Externalities Unit Values*, Austroads (www.austroads.com.au); at www.onlinepublications.austroads.com.au/items/AP-T285-14.

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.

Kate Marsh and Carolyn Watts (2012), *Literature Review on Community Severance and Social Connectedness: Definitions, Pathways and Measurement*, New Zealand Transport Agency (https://www.nzta.govt.nz); at https://bit.ly/34kTmwy.

Amy Nimegeer, et al. (2018), "Experiences of Connectivity and Severance in the Wake of a New Motorway: Implications for Health and Well-Being," *Social Science and Medicine*, Vo. 197: 78–86 (doi: 10.1016/j.socscimed.2017.11.049); at www.ncbi.nlm.nih.gov/pmc/articles/PMC5777829.

NZTA (2018), *Economic Evaluation Manual*, Volumes 1 and 2, New Zealand Transport Agency (www.nzta.govt.nz); at www.nzta.govt.nz/resources/economic-evaluation-manual.

SSTI (2021), *Measuring Accessibility: A Guide for Transportation and Land Use Practitioners*, State Smart Transportation Initiative (https://ssti.us); at https://ssti.us/accessibility-analysis.

Street Mobility Project (www.ucl.ac.uk/street-mobility). This Toolkit by the University College London identifies ways to evaluate walkability and ways to reduce pedestrian barriers.

Alejandro Tirachini (2011), *Effects of Pedestrian Mobility Barriers on Walking Distance*, Institute of Transport and Logistics Studies (www.sydney.edu.au).

Lucy Wallwork (2018), *Community Severance: How the 'barrier effect' Works*, Multi Briefs (https://exclusive.multibriefs.com); at https://bit.ly/3sJMHsu.