Walking and Cycling International Literature Review

Final Report

PREPARED FOR
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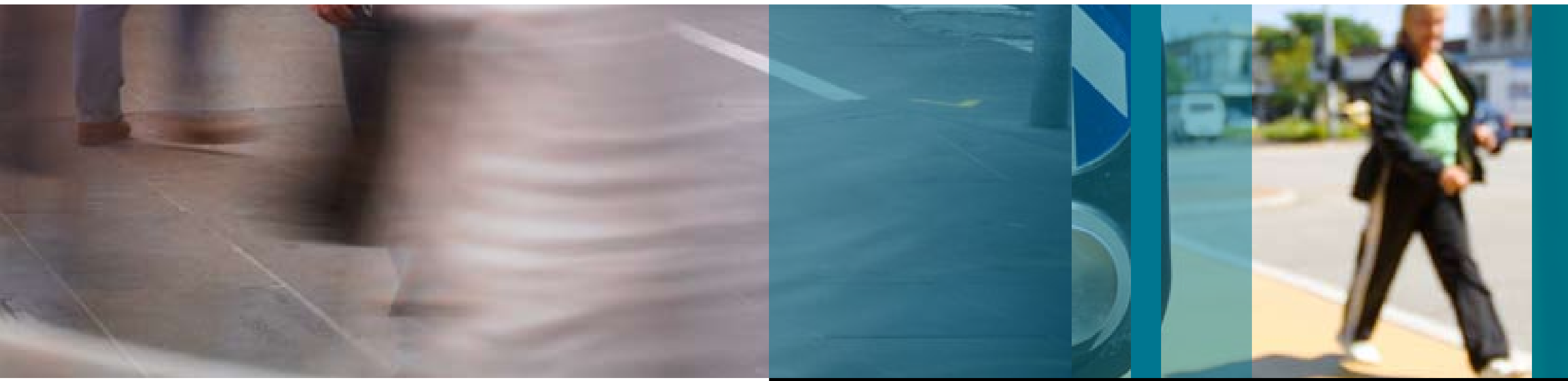
Victoria
The Place To Be



Outline of report

This report was commissioned by the Victoria Department of Transport and is made available for the purposes of promoting public discussion. However, the views expressed in the report are those of the authors. They do not necessarily reflect the views of the Department of Transport and may not reflect government policy or government recommendations and do not necessarily represent an action plan for government.

This literature review was commissioned by the then Department of Infrastructure in 2007 and undertaken by:

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At the time this report was commissioned, Dr Krizek was Associate Professor, Urban Planning and Civil Engineering, University of Minnesota and Dr Forsyth was Professor, Dayton Hudson Chair of Urban Design and Director, Metropolitan Design Center, University of Minnesota.

Please note that this report uses American spellings and some American terms. For those unfamiliar with American terms, please note the following.

AMERICAN TERM	AUSTRALIAN EQUIVALENT
Sidewalk	Footpath
Transit	Public Transport
Downtown	CBD or Central Business District
L.R.T.	Light Rapid Transit
Airline distance	"As the crow flies" distance
U.S.	United States of America
U.K.	United Kingdom

Glossary

Adequate pedestrian infrastructure and design: By adequate levels of pedestrian infrastructure and design we mean development is intense enough so that distances between destinations are not too great, the street system allows fairly direct pedestrian routes, and there are enough sidewalks or low traffic streets to provide options for getting to major destinations.

Bicycle box: Also called an advanced stop bar, is a right angle extension of a bicycle lane at an intersection, which allows cyclists to get ahead of automobiles after being stopped at a traffic light.

Bicycle loan programs: Provide free (or nearly free) access to bicycles for local transportation needs.

Carrots: Colloquial term used to describe the range of policy options serving to make something (NMT) extremely attractive, appealing or sometimes even irresistible.

Class A cyclists: Are experienced and are happy to operate on collector or arterial streets.

Class B cyclists: Include adults or teenagers who ride more occasionally and have less confidence in traffic than Class A cyclists.

Class C cyclists: Include children, the elderly, or other inexperienced populations who either do not ride on roads or where such activity is monitored by parents

Derived travel: Travel individuals do to engage in activities in other places—work, recreation, shopping, health services.

Hard measures: Physical factors directly affected by policy changes. May include development patterns, street layout, bicycle lanes, foot paths, intersections, bicycle parking, etc.

High quality pedestrian infrastructure: E.G., wide, tree-lined sidewalks with attractive paving, artistic street lamps, etc.

LOS: Level of Service models aim to provide a common rating system for facilities used by cyclists and/or pedestrians.

NMT: Non-Motorized Travel, including pedestrian and walking travel that is derived.

PMT: Person Miles Travel, used to refer to the distance for all travel, regardless of mode.

Programming: Educational initiatives or schedules of activities, procedures, etc., to be followed to encourage walking and/or cycling.

Rail-trail: Multi- or single-use trails running through former railroad corridors. Often grade separated from the adjacent road system.

Recreational travel: Travel individuals do for the sake of travel such as a walk around the park.

Self-selection: The phenomenon in which people choose a neighbourhood or employment area based partially on the amenities that area provides for their given travel preferences.

Soft measures: Non-physical factors directly affected by policy changes. Includes pricing of alternative modes, education, complex information exchanges, etc.

SBF: Separated Bicycle Facility, also referred to as a cycle track (mostly in the U.K.), sidepath, off-street bicycle paths, and sometimes Copenhagen bicycle lanes. For purposes of this report, SBFs are used in a general sense to include all of the above.

Sticks: Colloquial term used to describe the range of policy options serving to make something (NMT) very unattractive and/or expensive.

VMT: Vehicle Miles Travel, usually to reference the distance for all travel via motorized means (e.g., auto, motorcycle, or transit).

Voluntary Travel Behaviour Change (TBC): Changes in the travel choices people make, done of their own free will, without outside coercion or regulation.

SUMMARY OF FINDINGS

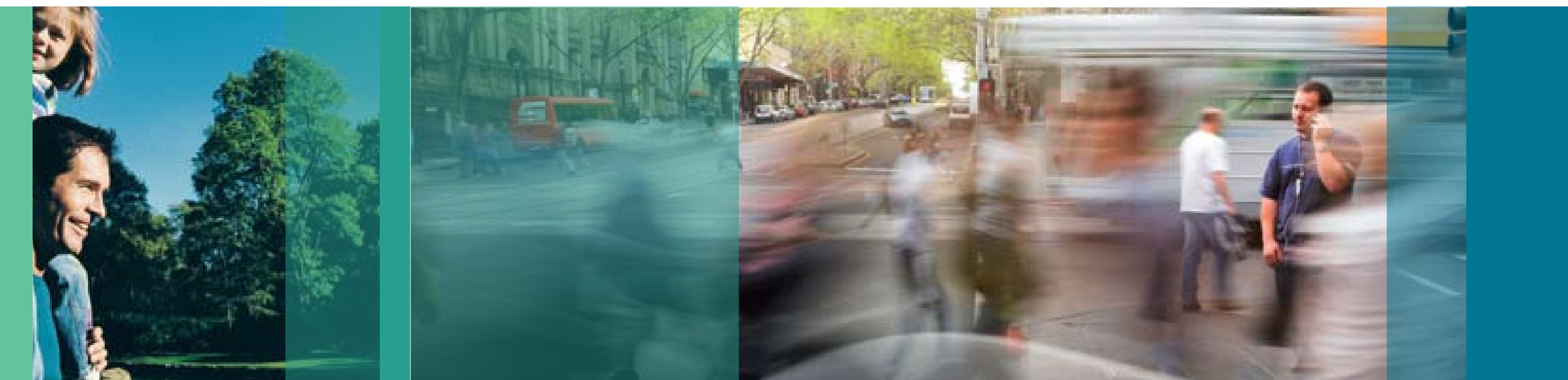
Why don't people walk or cycle more for day-to-day trip purposes? What can a government do to increase such walking and cycling? This report presents the findings from an extensive literature review aiming to help professionals and researchers in the State of Victoria understand barriers to walking and cycling as well as infrastructure and policy supports for non-motorized transportation. The research team located almost 500 articles, papers, and reports assessing walking and cycling infrastructure, policies, programs, and models. We reviewed over 300 of them—those judged to be most relevant to the questions raised by the Walking and Cycling Branch of the Department of Infrastructure and rigorous in terms of their analysis and ability to draw robust conclusions.

WALKING AND CYCLING COMMON THEMES

- *Combined factors:* Urban environments with high levels of walking and cycling typically represent a combination of many factors that help promote these modes of travel. The most compelling argument, particularly for cycling, is that only via an integrated range of environmental features (including infrastructure and facility improvements), pricing policies, or education programs will substantive changes result. This is what has been occurring in the Netherlands, Denmark, and parts of Germany for decades (Pucher and Buehler 2008).
- *Small interventions and perceptions:* The conclusion common to most studies is that small infrastructure interventions (micro-factors) have small or little effect on overall levels of walking and cycling. An exception to this finding is where gaps in the existing system are being remedied. However, small interventions often affect people's perception of pleasant walking or cycling environments which has positive outcomes. It should be emphasized, however, that it is an open question whether these positive perceptions about small interventions increase levels of walking and cycling at a population level. This is particularly the case for walking.
- *Focusing on robust results:* There are many studies that have significant findings not backed up by other studies. If researchers study enough variables, run enough regressions, and have enough observations they will uncover significant findings. At the 95 percent confidence level, 5 percent of findings will be significant by chance. Some findings are significant but the effects are very small. We addressed this issue by carefully attending to the specific type of Non-Motorized Travel (NMT), the population, and the context, and paying most regard to variables found to be significant across multiple studies, detailing this in Appendix A.

WALKING SPECIFIC FINDINGS

- *Walking vs. physical activity:* Recent U.S. literature from public health has focused on the built environment, walking, and total physical activity. The results are mixed or weak in terms of increasing total physical activity through environmental interventions. The results for travel walking, the focus of the walking part of this literature review, are stronger and more positive.
- *Perceptions:* Some studies find perceptions of the environment are important associations with walking for transportation; however, there is frequently little association between perception and reality (objective environment). That is, increasing infrastructure provision may not affect the perception of that provision. In areas where infrastructure and community design reach adequate levels, education and programming to change how people think and feel about the environment may be important. By adequate levels of pedestrian infrastructure and design, we mean development is intense enough so that distances between destinations are not too great, the street system allows fairly direct pedestrian routes, and there are enough sidewalks or low traffic streets to provide options for getting to major destinations. The bottom line then is, once environments are adequate it may be better to spend funds on programming around perceptions rather than greatly improving the environment, however, much more research is needed and we only state this to show the complexity of the tradeoffs and factors involved. The perceptions of parents about the safety of children is an important issue that has not been adequately dealt with in the literature; but it may well be that fear of stranger danger outweighs fear of traffic safety related to infrastructure.
- *Distance:* People will walk further than the 400 meters or one quarter mile that had been proposed anecdotally as a maximum walking distance, e.g., average distances over 600 meters to transit in Singapore (Olszewski and Wibowo 2005), and 40 percent of transit users living more than 300 meters airline distance from a stop in Toronto (Alshalalfah and Shalaby. 2007). Distance, however, is a real barrier for travel walking.
- *Carrots:* The U.S. literature is interested in carrots—can one make environments so attractive that people walk or cycle? Here studies have mixed findings but



community design features such as density and street pattern, or linkages to transit, may have more effect on travel walking than pedestrian infrastructure, amenities, and general aesthetics. Findings about sidewalks are mixed.

- *Sticks:* Sticks approaches seem to be effective in increasing overall levels of walking—making alternatives to walking very unattractive and/or expensive. These sticks include increasing the price and difficulty of driving and parking.
- *Populations:* Certain populations may be more sensitive to issues of high pricing of driving or parking or more positive about the incidental benefits of walking for exercise, social interaction, mental health, and such. They may also be more likely to live close to jobs, educational institutions, shops, and other transportation destinations. They value convenience and accessibility. These populations include: students, low-income people, and households without children.
- *Transitation:* In the U.S and likely in Australia, a major reason for walking in urban areas, is walking to and from transit (Besser and Dannenberg 2005; Agrawal and Schimek 2007). Besser and Dannenberg (2005, 273) find that "Americans who use transit spend a median of 19 minutes daily walking to and from transit." Better transit, including community or urban design to support such transit, can likely increase walking.

CYCLING SPECIFIC FINDINGS

- *Distance:* Cyclists are willing to travel longer distances than pedestrians, though there remains a decline in cycling, generally, after four kilometers or so. This distance varies dramatically depending on trip purpose. Entertainment, recreation, and fitness trips can reach 30 to 40 kilometers, while work and shopping trips typically fall within 10 kilometers. Based on findings from other successful cycling environments, there is a strong market for trips less than 2.5 kilometers.
- *Separated Bicycle Facilities (SBFs):* separated bicycle facilities such as off-road paths are not necessarily safer, particularly at intersections with vehicular traffic. However, they are perceived as being safer which may help less confident cyclists make the decision to ride a bicycle and may ultimately lead to higher levels of ridership.
- *On-street facilities:* On-street bicycle lanes, wide curb lanes, and other non-intersection specific treatments may be safer in high trafficked areas and intersections than separated bicycle facilities and are also much cheaper to install. Within this category of facilities, it is case specific over which facility is best. For example, bicycle lanes are typically not recommended on residential streets, where they cannot be maintained, or where "no parking" regulations are frequently violated.
- *Populations:* Those who stand to benefit most from the low-cost aspects of cycling are the young, the elderly, and the economically disadvantaged. These groups may also be most in need of separated bicycle facilities and other measures to increase sense of safety. Yet, the primary groups of cyclists in Australia and the U.S. do not fit into these categories.
- *Bicycle loan programs:* Research on these programs is scant and has shown few successes. However, a crop of new, technologically-advanced systems has received much attention in the popular press and may prove successful at increasing cycling and/or reducing Vehicle Miles Travel (VMT).
- *Transit:* Many bus, tram, and train systems allow bicycles on-board or provide attached bicycle racks. However, when integrating these two modes, the emphasis is often placed on improving access and safe parking at transit stops and stations. This is due to findings that suggest destinations are usually within walking distance of the egress point and bicycles are therefore less necessary for this segment of the trip.

The findings of the report are gleaned from and supported by a literature matrix in Appendix A, distilling the literature reviewed in terms of the following topics:

- Mode: bicycle, pedestrian, or both
- Type of intervention or environmental feature addresses: community design, infrastructure, mode choice, modelling, programming
- Literature type: peer reviewed, conference paper, report by agency, book, or other
- Approach: intervention, cross-sectional, etc.
- Place or density: big city, suburban, ex-urban, rural, etc.
- Sample: who, where, when, how collected, how many
- Outcome variables, that is type of walking and/or cycling examined

KEY SUMMARY POINTS AND RECOMMENDATIONS

We summarize the general findings by breaking down the range of strategies or policy levers that were studied into a handful of categories, along with a category labelled, "combined." Based on convergence of findings from the literature, we summarize the efficacy of various strategies for the two modes differently in Table 1. Dark shading represents features that are very important, lighter grey represents those of lesser importance, and no shading represents no reliable evaluations. For walking, community design and the use of multiple strategies is paramount. For cycling, the presence of mode specific infrastructure is most important, combined with the use of multiple strategies.

Table 1: Schematic showing the efficacy of different categories of policy levels

Strategy	Walking	Cycling
Community design		
Infrastructure presence	Matters more for children	
Infrastructure of high quality (e.g., wide, tree-lined sidewalks throughout)		
Programming		
Pricing and convenience		
Combined strategies		

Implications for each broad topic are listed at the end of each section and also summarised below. They are numbered by section e.g. point 1.1 is the first point in section 1.

1.1 Interventions for walking and cycling need to be considered separately as the modes have distinctly different characteristics and infrastructure needs.

1.2 Fully understanding NMT is an extremely complex endeavour that requires the analyst to wade through muddied waters and to consider multiple reasons for use and multiple outcome measures.

2.1 Pricing factors are tremendously important for spurring NMT. Auto and fuel taxation and parking are two factors that stand out. If motorized transportation is more expensive, people may well shift to non-motorized modes though they may also merely travel less or take transit.

2.2 The effect of education or other programs could be important, but more detailed and longer-term follow up evaluation is required in order to fully ascertain the benefits of such, particularly as it relates to NMT.

3.1 Community or urban design including gross population density, street pattern, and accessible destinations are important in creating a walkable environment.

3.2 While distance is very important for pedestrians, on average they will walk further than the anecdotal rule of thumb of 400 meters used in many planning applications.

3.3 The relationship between pedestrian infrastructure (particularly sidewalks) and walking is complicated. There are many reasons to provide such facilities and, if designed to be adequate for such motorized equipment as gophers and Segways, they will likely be adequate for pedestrians.

3.4 Perception of infrastructure is important in walking but it is not clearly related to actual provision. That is, providing more infrastructure may not in itself change perceptions. It is important to understand better how marketing and educational programs can be used to to modify people's perceptions of walkability.

3.5 Separated bicycle facilities are particularly troublesome in intersections involving automobile traffic and do not necessarily appear to be safer.

3.6 Separated bicycle facilities and related treatments lead to the perception of increased safety on behalf of the many cyclists.

3.7 Intersections are critical pinch points for cyclists and detailed treatments increase cyclists' comfort in navigating them.

3.8 Bicycle loan programs may have an impact in or close to urban core areas, where they are usually available, though scant evaluation precludes any conclusions at this point.

4.1 Planners should not underestimate the important role that predetermined preferences and lifestyles play in understanding rates of NMT. In some environments and for some populations, preferences may undermine the role that other initiatives—programming or infrastructure—may have.

5.1 NMT planning efforts could be substantially enhanced with greater information about NMT travel; this includes data collection efforts specifically geared toward better understanding the range, purpose, and impediments for walking and bicycling.

5.2 To best understand NMT travel, analysts require relatively small geographical units of analysis and detailed data about such environments (e.g., destinations as well as networks).

SECTION 1: INTRODUCTION

POLICY MOTIVATIONS AND CENTRAL QUESTIONS

The State of Victoria, much like other areas across the globe, has been wresting with concerns of increasing traffic congestion, depleting non-renewable resources, the threat of global warming, increasing obesity, and decreasing quality of life. The automobile is often targeted as a primary culprit for such problems (Forsyth *et al.* 2007a). Many fields are grappling with these issues. Non-motorized travel (NMT), particularly walking and cycling, seem to provide potential solutions.

Some professions, such as traffic engineering and urban design, have been planning for various forms of NMT for some time. Others are relative newcomers, for example, the recent interest in active transportation from the area of public health. Some see NMT as creating problems that must be addressed; for example, safety conflicts between motorists, cyclists, and pedestrians. Others see NMT as a potential solution to environmental and public health problems. Urban designers and many activists regard NMT as part of a vibrant, vital, and human-scaled public realm. Trails advocates, those from parks and recreation fields, and proponents of traffic calming and complete streets see NMT as either a central component, or at least an additional justification, for their favoured designs (Forsyth *et al.* 2007a).

There remain however, many questions about which factors lead to walking and cycling at the individual, interpersonal, environmental, and policy levels. This report examines existing literature to better understand how specific soft (non-physical) or hard (physical) measures influence walking or cycling travel behaviour. It is prepared for the Department of Transport (formerly the Department of Infrastructure) in Victoria, Australia, and is to be used by infrastructure professionals and researchers for three purposes:

(a) to wade through the existing knowledge base related to NMT,

(b) to identify plausible interventions, and

(c) to target future research directions.

While walking and cycling for recreation are important activities, the focus in this report is on active and derived travel, that is, the travel individuals do by walking or cycling to engage in activities in other places—work, recreation, shopping, health services (as opposed to travel for the sake of travel such as a walk around the park). The focus on derived travel (sometimes referred to as utilitarian travel) suggests there are different emphases or findings than if we were to focus on recreational travel as well.

In the main report we synthesize findings from available literature in a thematic manner that is more easily understood than simply recounting batteries of studies. The main body of this report is therefore a higher level assessment, focusing on findings that converge from a number of studies and placing the literature in context. The companion literature matrix in Appendix A provides an overview of the literature on walking and cycling, summarizing over 300 specific studies out of almost 500 relevant studies that we located addressing dimensions of NMT that are relevant to the concerns of the Department of Transport. In order to conduct the literature review we searched several major transportation, urban planning, and health databases including TRIS online and Medline. We conducted an internet search for reports published by government, advocacy or other organizations. Krizek and Forsyth then classified the entire list into two tiers of studies.

Articles that are summarized in Appendix A are classified as Tier 1 and those we list in the bibliography but do not summarize are called Tier 2. Tier 1 studies have the following characteristics.

- Studies that demonstrate high quality with refereed articles preferred.
- Such works typically comprise empirical studies with strong data and research methods or systematic reviews of such studies.

Tier 2 studies are relevant to concerns of the Department of Transport and have characteristics that demonstrate quality and/or relevance. They include reports from reputable organizations and some conference papers. These may include work based on an assessment of a significant infrastructure design, other development experience or best practices. While some Tier 2 studies are referred to in the report (and are included in the bibliography at the end), only Tier 1 studies appear in Appendix A.

The literature review is international but includes only literature in English. In addition, there are many parts of the world with interesting interventions—for example parts of Europe and Latin America—but little rigorous evaluation of such. As this review is of studies that included evaluation rather than description, these interventions are under-represented.

STUDYING MUDDIED WATER

The body of research on walking and bicycling, while relatively new, can be nuanced and complex. Consider for example, the multiple ways in which one particular study could measure walking for transportation: number of trips, total distance of trips, minutes spent walking, trips over 10 minutes, percentage of total trips, purpose of trips, etc. And this is just a few of the ways that walking for transportation has been measured! What happens when cycling is also thrown into the fray? The waters become muddied very quickly, resulting in situations where findings from one study appear to contradict the results from another.

Similarly, there is enormous variety of potential pedestrian and bicycle improvements that may be used alone or in combination with each other and with urban design strategies. These include infrastructure: paths (sidewalks or sidewalks, bicycle or multi-use trails, on-street bicycle lanes), crossings (signalised, striped, coloured, underpasses, overpasses, refuges), specialized streets (pedestrian malls, shared streets), intermodal connections (bus shelters, train stations, bicycle parking areas), and destination level facilities (change areas, bicycle repair). However they also include more general community or urban design, policies, programs, marketing, and information.

In addition, even if studies are examining similar behaviours (outcome measures, dependant variables), they might differ radically in the population studied (the sample), the environment or context (central city versus suburban versus rural), the number of control variables employed, the devices or survey instrument used to measure the outcome measure, the analysis strategies employed, the emphasis on discerning "transportation" related travel versus "recreational" related travel, etc. This report focuses primarily on walking and cycling for transportation, however, a non-motorized "trip" may combine travel with exercise or leisure (Forsyth *et al.* 2007a).

DECISION TO WALK OR BIKE: MOTIVATIONS AND BARRIERS

The decision to walk or bicycle is ultimately a behavioural one. Individuals only engage in the activity once several criteria are satisfied. For NMT, a typical thought process for such can be broken down into three parts: initial considerations, route considerations, and destination related considerations. To satisfy each of these, several factors stand in the way. In most developed communities across the globe (outside select areas in Northern Europe), there are more reasons not to walk or bicycle than there are to walk or bicycle. Like many aspects of human behaviour, pinning down reasons to explain NMT travel behaviour is fraught with difficulty.[1]

Impediments to NMT generally divide themselves along two tracks: complex policy relevant factors and direct policy relevant factors. Each is briefly described in turn below and examined in more detail later in the report.

Figure 1: Factors Affecting NMT Use

Complex Policy Implications

e.g.,
– Weather
– Topography
– Social responsibilities

Direct Policy Relevance

Soft measures

e.g.,
– Pricing
– Education/programming

Hard measures

e.g.,
– Infrastructure
– Community design
– Crossing treatments
– Bicycle loan programs

NMT is susceptible to several factors that are easily overcome by motorized travel but that require complicated policy and infrastructure responses to make non-motorized transportation attractive:

- *Climate and topography:* Rain, cold, and slopes pose challenges for NMT; the latter is particularly an issue for cycling (Bergstrom and Magnusson 2003). Scarf and Grehan (2005, 919) analysed the role of hilliness in cycle travel time and found that "1 m of vertical travel on a bicycle can be considered to be equivalent to approximately 8 m of horizontal travel." Rainy (or dark) conditions affect users' perceptions of the safety of travel. Cold or wet conditions affect one's personal comfort level while travelling. Clothing and umbrellas can moderate these effects, programming and education may alter perceptions of these features, some physical infrastructure such as up-hill cycle lanes can lessen the burden, and transit can provide a means of avoiding them temporarily through motorized transportation without using personal vehicles. However, they are complex issues to address.
- *Speed and distance:* NMT is also limited in speed and distance—an issue in rural areas and for those wishing to access many parts of a metropolitan area.
- *Carrying things:* Carrying parcels or passengers is also more difficult for pedestrians and cyclists. While children can walk or cycle, they are even slower than adults and need more attention than when strapped into a car seat (Forsyth *et al.* 2007a).

For example, "Although well-connected streets, small city blocks, mixed land uses, and close proximity to retail activities were shown to induce non-motorized transport, various exogenous factors, such as topography, darkness and rainfall, had far stronger influences" (Cervero and Duncan 2003, 1482). Factors that are more directly affected by

[1]There is a reason, after all, that in most studies aiming to predict various dimensions of travel behaviour, more than 70 percent of the variation in the data goes unexplained (e.g., that is, an R^2 of less than 3).

policy changes in areas of relevance in planning and engineering come in two forms—soft and hard measures. Research examining the efficacy of these factors is reviewed for this report. Soft measures are non-physical such as pricing of alternative modes and education. Some involve relatively complex information exchanges between peers, for example sharing information with a co-worker about bicycle routes to work (Krizek *et al.* 2007b). Hard measures are physical—development patterns, street layout, bicycle lanes, foot paths, intersections, bicycle parking, and so on.

DIFFERENCES BETWEEN WALKING AND CYCLING

While both walking and cycling are non-motorized—along with such modes as animal-powered carts—they are significantly different. It is useful to consider them together when advocating for additional attention to non-motorized travel. However, when designing policy responses, the differences between them are important as is explained in Figure 2 (Krizek *et al.* 2007b; Forsyth *et al.* 2007a). Future research and practice are likely to consider walking and cycling independently; the initial charge for this literature review separately outlined the learning outcomes for walking and cycling and we underscore this as important (Forsyth *et al.* 2007a).

Figure 2: Key Differences Between Walking and Cycling

Dimension	Specific to walking	Specific to cycling	Key differences
Participants	Almost everyone except some with mobility impairments.	There are at least 3 different types of cyclists: A (Advanced), B (Basic), and C (Children)	Cyclists demand more specific environments, depending on participants or purpose; also require more physical skills (e.g., balance).
Range/scale	Mostly up to a mile (1.6 km) in length. The average trip length in the U.S. is 1.2 miles (1.93 km); between 47% and 60% of walking trips are less than 0.5 miles (0.8 km). Recreation/work trips tend to be longer.	Local and regional cycling. The average trip length is 4 miles (6.44 km) and 57% of cycling trips are less than 2 miles (3.22 km).	Cyclists travel much further.
Speed	Depends on the purpose of trip; ranging from 1 mph (1.6 km/h) (dawdling) to top speeds around 4-5 mph (6.44-8 km/h) for more active walking.	Usually range from 8 mph (12.9 km/h) to 20 mph (32 km/h).	Cyclists travel much faster.
Infrastructure	Infrastructure requirements for safe use include sidewalks (or paths, esp. for children). However, exemplary pedestrian environments may also contain attractive streetscaping.	Can share roads with cars though with safety issues; lanes and paths are options; need infrastructure at destinations (parking, showers)	Cyclists require more infrastructure at destinations
Infrastructure planning responsibility	Local land use planners, and transportation planners; also considered in subdivision layout and urban design.	Engineers and transportation planners responsible for on-road infrastructure; parks and recreation planners for off-road.	Responsibility does not always coincide, making coordination more difficult.
Trip purpose	Transportation (including accessing other modes, e.g., parked cars, transit) and for recreation travel	In the U.S., a clear majority of bicycle trips are related to exercise, health or recreation; cycling for transportation often plays a stronger role in many other cultural settings.	Cycling primarily viewed as a recreational activity, at least predominantly in the U.S.
Safety concerns	Crime (real and perceived); safety from traffic at crossings and on streets without sidewalks.	Safety from traffic, particularly in narrow streets and at intersections with roads.	Pedestrians are concerned about avoiding areas of high crime; bicyclists' prominent safety concern often stems from automobile traffic.
Key barriers	Distance or perceived distance? Safety from crime or traffic.	Distance. Safety from traffic. Cost of equipment?	
Interface with automobiles	Mainly at intersections, but also any locale without sidewalks.	Bicycles are often perceived as unwanted distractions in existing roadway space; conflicts also occur where trails intersect with streets.	Cyclists often perceived to be competing for limited roadway space with automobile drivers.
Interface with transit	Focus on the area around bus or LRT stops to make them pedestrian accessible and attractive for walkers.	Require front racks or other means to accommodate bicycles. Requires parking at transit stops.	Cyclists are more cost prohibitive to account for.

Table source: Adapted from Forsyth et al., 2007a. Original sources for table: Oregon Department of Transportation (1995); Forester (1994); Zegeer (1998); Statistics from U.S. National Highway Traffic Safety Administration and U.S. Bureau of Transportation. (2002); Bureau of Transportation Statistics (2003). Note: Distances and speeds in blue converted by DOT.

As is explained in Figure 2, most people walk, and most are sensitive to distance. Route choice options serve to enhance safety, interest, and the ability to stop off at multiple destinations on the same route (Hess *et al.* 1999; Humpel *et al.* 2004a, 2004b; Forsyth *et al.* 2007b). For many years urban designers dominated this literature with transportation planners only addressing the pedestrian environment in passing (Gehl 1987; Jacobs 1993; Zegeer 1995).

By contrast, far fewer people cycle than walk. Cyclists can move further and at greater speeds than pedestrians, resulting in the need for cycling facilities to be longer. Cycles are legally considered vehicles in many areas and cycling requires equipment to conduct the activity and to park at the beginning and end of each trip (Forsyth *et al.* 2007a). While there are different types of pedestrians, cyclists have been commonly classified into three classes—a critically important point if one is to fully understand the merits of different infrastructure treatments.

Class A cyclists are experienced and are happy to operate on collector or arterial streets. Class B cyclists include adults or teenagers who ride more occasionally and have less confidence in traffic. Class C cyclists include children, the elderly, or other inexperienced populations who either do not ride on roads or where such activity is monitored by parents (Krizek *et al.* 2007b). In each case the presence of cars provides safety concerns and/or causes cyclists to avoid roads. But, it is critical to understand that, relative to pedestrians, there is much wider variation in how different types of cyclists respond to different types of infrastructure treatments.

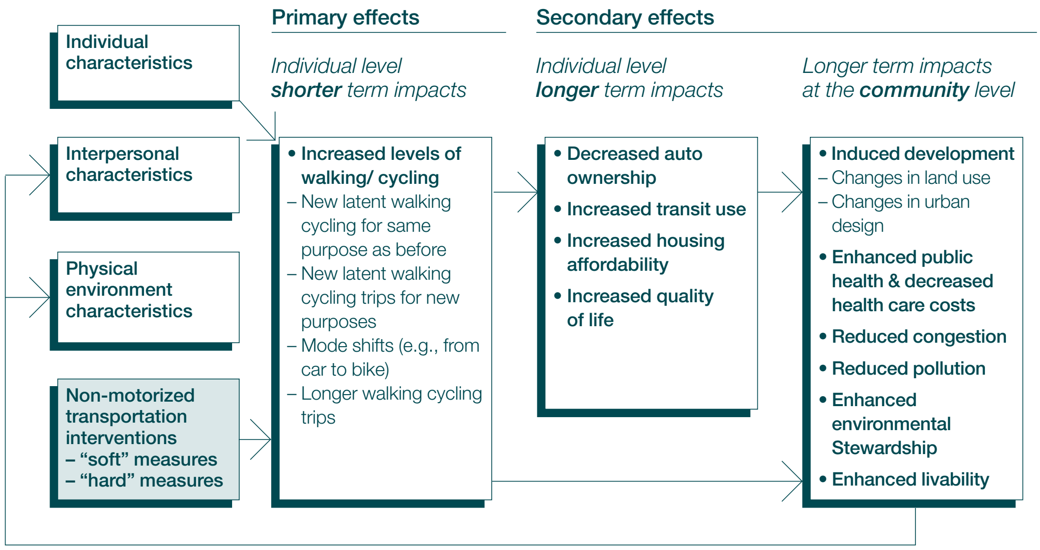
When directly comparing the differences between walking and cycling, it becomes apparent that the two modes are often more different than they are similar. Therefore, efforts to account for NMT in future planning applications often need to use different strategies as the infrastructure requirements and environmental supports for each vary too much.

CONCEPTUAL FRAMEWORK FOR INCREASED WALKING OR CYCLING

Increased use of NMT requires behavioural change—change that theoretically results from a combination of soft and/or hard measures, in addition to complex policy relevant factors. The interventions from hard measures mostly require changes to the built environment—changes that would increase the access, attractiveness, safety, comfort, and security of NMT. Additionally, they may stimulate changes in perceptions, attitudes, and other psychological factors similar to those anticipated by soft measures (Krizek *et al.* 2007b).

Increased walking and cycling may (a) replace motorized trips, (b) be new, or (c) be longer. In the longer term this may lead to secondary effects such as changed individual car ownership or community-scale reductions in traffic congestion (Krizek *et al.* 2007b). Many such secondary effects have been identified and include better air quality, improved health, and liveable cities (Figure 3). Some of these secondary benefits have complex causes and the exact contribution of non-motorized transportation is difficult to assess. Such complexity is also the case for issues like traffic congestion and obesity (Krizek *et al.* 2007b). Overall, it is crucial to assess actual effects rather than assuming that effects are significant and in the expected direction.

Figure 3. Typical Conceptual Framework



Source: Krizek et al. 2007b.

Summary

1.1 Interventions for walking and cycling need to be considered separately as the modes have distinctly different characteristics and infrastructure needs.

1.2 Fully understanding NMT is an extremely complex endeavour that requires the analyst to wade through muddied waters and to consider multiple reasons for use and multiple outcome measures.

What Victoria has done

The Victorian Government has a number of strategic documents that provide a future vision, information and resources for NMT. Three key documents articulate the future of transport planning and policy in Victoria. *Melbourne 2030* is a land use and transport plan for the metropolitan area which focuses on growth and sustainability (Department of Infrastructure 2002). The *Linking Melbourne: Metropolitan Transport Plan* integrates the principles of *Melbourne 2030* and focuses on four key issues as they relate to transport: safety, congestion, population growth and economic growth (Department of Infrastructure 2004). In 2006, *Meeting our Transport Challenges* was released, providing a 25-year framework designed to shape transport planning across Victoria, integrating strategies from the two plans (Department of Premier and Cabinet 2006).

In addition there are a number of surveys and programs. These include:

Surveys

- Victorian Activities and Travel Survey (VATS) – travel surveys were conducted throughout Melbourne from 1994 to 1999 (ABS, 2000).
- Victorian Integrated Survey of Travel and Activities (VISTA) – travel survey results to be released in 2009 (Department of Transport).

Programs

- TravelSmart – a travel behaviour change (TBC) program that operates through grants, policy support and programs targeting municipal governments, workplaces, schools, and communities (Department of Infrastructure 2007b; 2007c).
- Local Area Access Program (LAAP) – grants that support a range of small-scale infrastructure projects aimed at demonstrating the benefits of improved access at the local level.
- Walking and Cycling Infrastructure Program, delivered by VicRoads.

SECTION 2: SOFT MEASURES: PRICING, PROGRAMMING, AND EDUCATION

PRICING: THE LOW COST OF DRIVING/PARKING

In any effort to learn about NMT, it is critically important to understand the broader context of relative pricing in choices among different modes and, for cycling, the availability of vehicles (i.e., bicycles). Furthermore, pricing considerations are not limited to the strict monetary costs but are also related to the convenience, parking, and duration of a trip.

In many developed countries—especially the U.S. and Australia—it is well documented that auto users, on average, pay less for mobility privileges than other modes of transport. The most notable examples of car use subsidization come in the form of the financing for roadways, parking, and extremely low fuel taxes. Leveraging policies to affect these dimensions promotes a more level playing field where auto users assume a larger share of the costs for the externalities (e.g., pollutants) they generate.

Two pricing factors that are extremely influential, large scale, and directly affected by policy include the costs or taxes assessed for auto travel (in the form of petrol) and the costs associated with parking. For the former, it is well documented that variations in travel behaviour arise largely from public policy differences, especially from differences in automobile taxation (see Pucher 1988, for example, for differences between Western Europe and North America). Furthermore, increases in gas taxes are seen as an equitable and cost efficient strategy in striving for a more balanced transportation system (Wachs 2003).

For the latter, the strongest—and most direct—policy lever to spur NMT comes in the form of parking policies for automobiles. In the U.S., it is estimated that 99 percent of all car trips begin and end at a parking space that is free to the driver (Shoup 2005)—a factor that goes a long way when one considers the overall costs and benefits of a walking or cycling trip. Not only does ample and free parking provide an easy excuse for auto travel, vast parking areas are also the bane of pedestrian travel. Various examples are well documented where the marginal cost of parking has been internalized to the users, thereby resulting in higher rates of non-auto use (Shoup 2005). A pooled study of almost 900 people in Minnesota and Maryland, controlling for a variety of socioeconomic factors, found the perception of parking difficulty was the strongest association with weekly travel walking and total walking measured by survey (Rodriguez *et al.* 2007). Other factors with either no or very weak associations included several measures of transit access (perceived and measured): sidewalks (perceived and measured), bicycle paths, and crosswalks, perceived traffic, and perceptions of many destinations. Other instances come from the urban design experiments correlating gradual decreases in parking availability, such as in Copenhagen, with a general upturn in pedestrian activity.

Finally, as we report below, many studies find that people with low incomes walk more for transportation indicating that pricing considerations are likely at work. For example, Van Lenthe *et al.* (2005, 763) drew on a survey of 8,767 adults in the Netherlands and found that "compared to those living in the most advantaged neighbourhoods, residents living in the quartile of socioeconomically most disadvantaged neighbourhoods were more likely to walk or cycle to shops or work, but less likely to walk, cycle or garden in leisure time and less likely to participate in sports activities (adjusted for age, sex and individual educational level)." Agrawal and Schimek's (2007) work with a nationwide survey of 26,000 people in the U.S. arrived at similar conclusions.

While this literature review was not tasked with the responsibility of focusing on these dimensions, it is necessary to understand the strong influence pricing factors—broadly defined—have in affecting mode choice.

PROGRAMS AND EDUCATION OR SOCIAL MARKETING EFFORTS

Programs and education efforts come in many different forms, ranging from formal to informal, personalized journey planning to blanket promotional material. Many programs focus on the concept of voluntary travel behaviour change (TBC), which involves people making choices to change their travel behaviour of their own free will without outside coercion or regulation. Examples include: marketing programs, walking clubs, or school-based programs. Some efforts work with individuals or households to understand their personal travel needs and make them aware of feasible or even attractive NMT travel options of which they were previously unaware. General efforts of these sorts go by various names such as travel blending, travel smart, or personalized travel planning. The central theme in these efforts is that certain populations could benefit from either additional motivation or support or the appropriate information to engage in higher levels of NMT.

The direct effect of such programs on NMT, however, is relatively unclear because many of these efforts are also geared toward less auto travel (in terms of distance) and more transit use, and are not centred on walking or cycling. Other programs focus on increasing transportation walking for the health benefits it provides. These programs typically come from the public health field and often target specific populations, such as school children or rural populations.

Nonetheless, *some* evaluation work has been completed. The little research conducted on non-infrastructure-based school programs has found some positive results, though methodological and other factors may temper some of these findings (Staunton *et al.* 2003). Oliver *et al.* (2006) reported on an intervention that included a four-week elementary school curriculum in New Zealand; there was no significant effect on the whole sample but the most sedentary children did increase their number of steps.

Research on adults is more mixed and has tended to focus on walking rather than cycling. These programs are typically designed by the researchers for a specific set of participants and use informational materials, phone calls, and in-person meetings to encourage increased physical activity. Most of these programs do not distinguish between trip purposes, meaning transportation trips are not explicitly identified. Some find modest but significant behaviour changes although follow-up periods are typically months rather than years (e.g., Ball *et al.* 2005; Goulias *et al.* 2002). Some merely measure at the end of the intervention (Clarke *et al.* 2007; Dinger *et al.* 2005; Haines *et al.* 2007). Others find no significant changes compared with controls (e.g., Brownson *et al.* 2005) or comparing minimal versus more sophisticated interventions (Chen *et al.* 1998).

In terms of cycling, Merom *et al.* (2003) surveyed 450 adults who owned bicycles, interviewing them by phone both before and after a promotional campaign advertising the opening of a bicycle trail in western Sydney. They found a slight increase in awareness and an increase in cycling time for those close to the trail (within 1.5 kilometers), but in terms of overall physical activity this was more than offset by a decrease in walking. Overall cycling did not increase because of the trail although one subgroup—those from a non-English speaking background living close to the trail—did increase cycling time mainly due to a few participants using the trail to commute to work (p. 239).

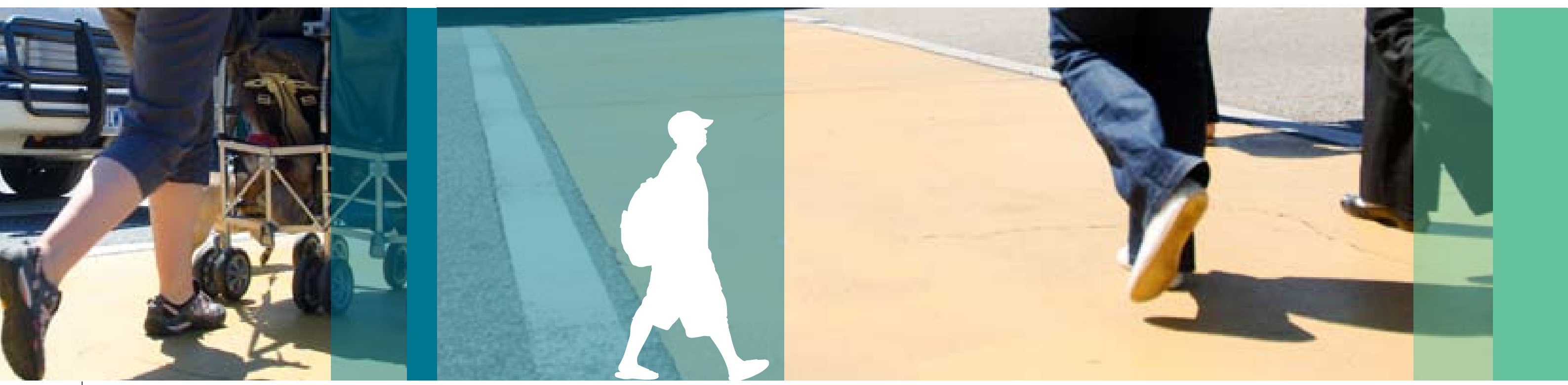
However, Mutrie *et al.* (2002) found a significant change in the numbers of participants actively commuting to work by walking 12 months after receiving an information packet in a work-based program aimed at people who had irregularly commuted; cycling did not change. Reger *et al.* (2002) in a paid media and public-relations based intervention focused on sedentary older people and reported a significant increase in people observed walking. Ogilvie *et al.* (2004), based on a literature review, estimate such targeted campaigns can shift 5 percent of trips though it is not clear over what period.

Ultimately, more research is needed to determine how useful “soft” programs are in the long term. We imagine they may be most successful when combined with other strategies such as increased transit services, and increased pricing of driving and parking.

Summary

2.1 Pricing factors are tremendously important for spurring NMT. Auto and fuel taxation and parking are two factors that stand out. If motorized transportation is more expensive, people may well shift to non-motorized modes though they may also merely travel less or take transit.

2.2 The effect of education or other programs could be important, but more detailed and longer-term follow-up evaluation is required in order to fully ascertain the benefits of such, particularly as it relates to NMT.



SECTION 3: HARD MEASURES: COMMUNITY AND INFRASTRUCTURE DESIGN

COMMUNITY DESIGN

Community design refers to the location and type of different land uses, the overall street pattern (grid versus cul-de-sac), and the intensity of development. Nearly all literature from this line of research focuses on the extent to which such characteristics result in less auto use. However, heightened levels of NMT may not always be accompanied by lower auto use; NMT may complement auto travel rather than substitute. Or, lower levels of auto use may be consumed by transit trips. In addition, most studies combine walking and cycling, thereby masking the true impact for any one mode.

Where research has explicitly studied walking and/or cycling, it has typically aimed to tease out the impact of one or more specific factors, such as the distance to various establishments (such as retail) or measures of density (which are basically proxies for one another).

Walking findings

Adults: Many studies show community design is important for adult travel walking including street pattern, density, and mixed use or destinations (infrastructure is dealt with in the next section). However, studies contradict each other. For example, an early study by Cervero and Duncan using two-day travel diaries and a number of GIS-based measures focused on the built environment found only land use mix at the origin was statistically significant in a model predicting walk trips under five miles (2003, 1401).

More recently, Lee and Moudon (2006b) asked 438 respondents in Seattle about the last week of walking “(a) to work, (b) to school, (c) to grocery stores, (d) to other retail or service facilities, and (e) for recreation or exercise” (2006b, S81). After analyzing dozens of environmental variables using GIS they proposed several variables that facilitate walking, for leisure **or** travel. Travel walking, measured as any walking vs. non-walking or frequent walking versus non-walking, was associated with distances to office and mixed use center, restaurants, bank, post office, and grocery store; along with slope, parcel density, and area density (Lee and Moudon 2006b, s88, s93). Sidewalks were not significant. In another study, Forsyth *et al.* (2007b, 2008) measured dozens of density, land use, street pattern, and infrastructure characteristics in a study of 715 people in Minnesota. They found associations between travel walking, measured via survey and travel diary, and various measures of population density and connected street patterns, sidewalks, social land uses (such as libraries, day care, clinics, theaters, sports areas, recreational facilities, and houses of worship), and litter and graffiti measured via observations. It should be noted however, that these and other similar studies measure dozens of variables and find only a few to be significant.

Overall, density, street pattern, and destinations seem to be identified in many studies. These relate closely to distance as they are measures of the closeness of things and directness of routes. A review of national data based on a one day travel diary filled out by 26,000 households, found 8.7 percent of trips were walk-only and almost all the 2 percent of transit trips started with a walk trip. However, 35 percent of respondents did not report walking at all that day. For those that did, the median trip was only 0.25 miles (402 meters) but the average walk trip was 0.62 miles (998 meters) and 23 percent of walk trips were over one mile or 1609 meters. Approximately 20 percent of trips were to and from recreation or for recreation and those with higher educations were much more likely to take such trips, confirming other research (Agrawal and Schimek 2007). Agrawal and Schimek found utilitarian walking increased with very high population densities (25,000 people per square mile measured at the census block group level, or 97/ha), zero ownership, the lowest incomes, and higher educational levels.

These findings are echoed by those such as Olszewski and Wibowo (2005) who found similar average walking distances of over 600 meters to transit in Singapore and Alshalalfah and Shalaby (2007) who found more than 40 percent of transit-riders in Toronto lived more than 300 meters airline distance from transit (likely at least 400 meters on the street network). It is apparent that some people will walk far further than the anecdotal cut off of 400 meters often cited in planning studies. The issue is, are these walkers already doing it, or is there a market for increasing walking? Can accessible destinations be increased by increasing development intensity and if that is done, will more people walk to them?

For children, the perceptions of their parents about such issues as traffic safety and stranger danger are such strong mediators that the relationship between overall community or urban design and their walking is a complicated one. However perceived distance, which is related to community design, emerges as the key barrier to children walking to school in several studies (Black *et al.* 2001; CDC 2005). More work, however, has focused on infrastructure and education interventions and we deal with that below.

Cycling findings

Tenets of community design are often implicit in many bicycling related initiatives because cycling has been shown to be highly attractive for short distance trips. After all, unless common and attractive origins and destinations are brought together within feasible distances—a feature of community design—such trips would likely not be realized. Two outstanding questions are: (1) is there currently a large enough market of relatively short haul trips between common origins and destinations to make a difference (i.e., is the existing urban form/community design compatible for such), and (2) how close is close enough for people to want to walk or cycle?

Bicyclists are willing to travel much longer distances than pedestrians, largely due to higher average

speeds attainable by bicycle. At the same time, however, distance remains an important constraint in terms of bicycling use and the distance between common origins and destinations is a critical dimension of community design. For example, part of the reason European cities have higher rates of NMT use than the U.S. is that average trip distances, regardless of mode, are shorter, presumably due to denser development patterns than many other settings. A relatively high percentage of all trips in European cities are shorter than 2.5 kilometers: 44 percent in the Netherlands, 37 percent in Denmark, and 41 percent in Germany, compared to 27 percent in the U.S. (Pucher and Buehler 2008). These general transportation facts yield a strong market for cycling trips. However, as is reported below, Melbourne also has short trips but not the same number of cyclists.

Other and more detailed dimensions of community design are also important in understanding specific types of trip purpose. For example, using detailed findings from analysis of the Twin Cities (U.S.) metropolitan area, we find that entertainment, recreation and fitness trips appear to cover the greatest average distances with some trips reaching 30 to 40 kilometers (18.6 to 24.8 miles). Work trips by bicycle are the next longest type of trip, with most trips falling within a range of about 20 kilometers. Bike trips for work, shopping, or access to bicycle trail facility tend to be shorter on average, with the majority of trips falling within 10 kilometers (6.2 miles). Trip purpose is an important factor in determining the length individuals are willing to travel by bicycle (Iacono *et al.* 2007). In a review of studies from the Netherlands, Germany and the U.K., Martens (2004, 281) found that the majority of cyclists riding to transit "travel between 2 and 5 kilometers to a transit stop, with longer access distances reported for faster modes of transit." That is, people will cycle further for a regional train than an ordinary city bus.

INFRASTRUCTURE

When most people consider efforts to induce NMT, their thoughts turn to matters of infrastructure, specifically infrastructure required for walking or cycling. Relative to overall community layout, infrastructure for pedestrians can be retrofitted in many cases with modest expense. Infrastructure for cyclists is often more expensive. Overall, NMT is unique in terms of more general transportation infrastructure because of the varied types of facilities on which it occurs and the need to consider varied types of users. Outside of freeways, almost all roadways and neighbourhood streets are NMT facilities (of course some are safer than others). There are NMT mode specific facilities—sidewalks for walking and bicycle lanes for cycling. There are also combined facilities for NMT movement. Because of the specific nature of each of these types of infrastructure, the literature on each type is discussed in turn.

Walking findings

The big picture findings can be divided by population group.

Given basic provision of infrastructure, **adults** walking for transportation can do so if given fairly basic sidewalks or low traffic streets to provide options for getting to major destinations (Hoehner *et al.* 2005; Forsyth *et al.* 2008). A number of studies of **adults** have not found general sidewalk provisions to be associated with travel walking (e.g., Lee and Moudon 2006b, s77); others do find them significant (Forsyth *et al.* 2008) but the findings are mixed. Sidewalks are likely most critical on major roads as compared to residential streets. As is noted below, if pedestrian infrastructure is made adequate in network coverage, size, smoothness for motorized wheelchairs and such, as legal requirements and equity concerns often dictate, it will likely be wide and even and continuous enough for pedestrians.

For example, Hoehner *et al.* (2005, 105) found that after adjusting for age, sex, and education, walking for transportation was negatively associated with (measured) sidewalk levelness but positively associated with a number of community design features such as "perceived and objectively measured access to destinations and transit" as well as "perceived access to bike lanes, and objective counts of active people in the neighbourhood." Perhaps older neighbourhoods with less level sidewalks had community design and socio-demographic features supportive of walking. Other studies have examined provision of street trees, lighting, buffering for pedestrians, crosswalks, and such and have mixed findings. Forsyth *et al.* (2008) found lighting but not street trees increased travel walking in Minnesota. Community design features such as high densities, connected street patterns, and some types of land uses are typically more important as are social and economic factors.

Perception is also important; some find more important than the objective environment (McGinn *et al.* 2007) but it is not clearly related to actual provision. That is, increasing provision of features such as sidewalks may not increase perception of that provision. Studies that examine the correlation between perceptions of the environment and the actual environment show little relation (McGinn *et al.* 2007).

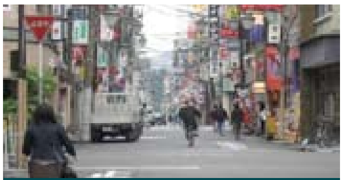
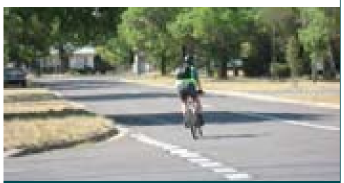
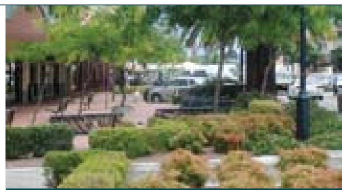
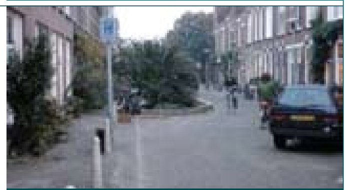
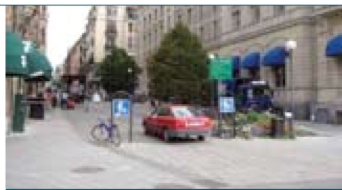
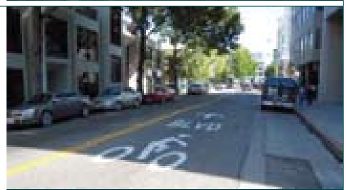
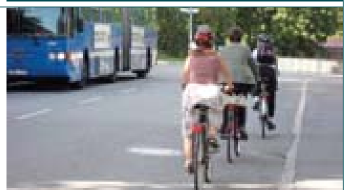
However, **children** are less confident dealing with cars and their parents may be less willing to let them walk in areas without infrastructure such as sidewalks. Ewing *et al.* (2004) using travel diary data found distance and sidewalks on main roads were associated with walking to school although as in other studies they found high income and access to cars decreased active transportation. For example, Boarnet *et al.* (2005a, 2005b) found parents reported more children walked to school after relatively simple but publicized sidewalk gap closure projects in California's Safe Routes to Schools program.

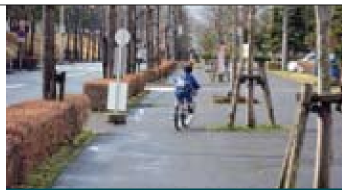
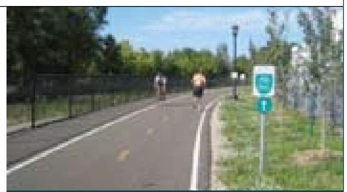
A review by Dumbaugh and Frank (2007) found that while there are gaps in the literature, sidewalks and raised medians do decrease incidence of pedestrian crashes (but crosswalks did not). Low traffic speed has been found in numerous studies to decrease accidents, or at least their severity, so traffic calming mechanisms may also be useful.

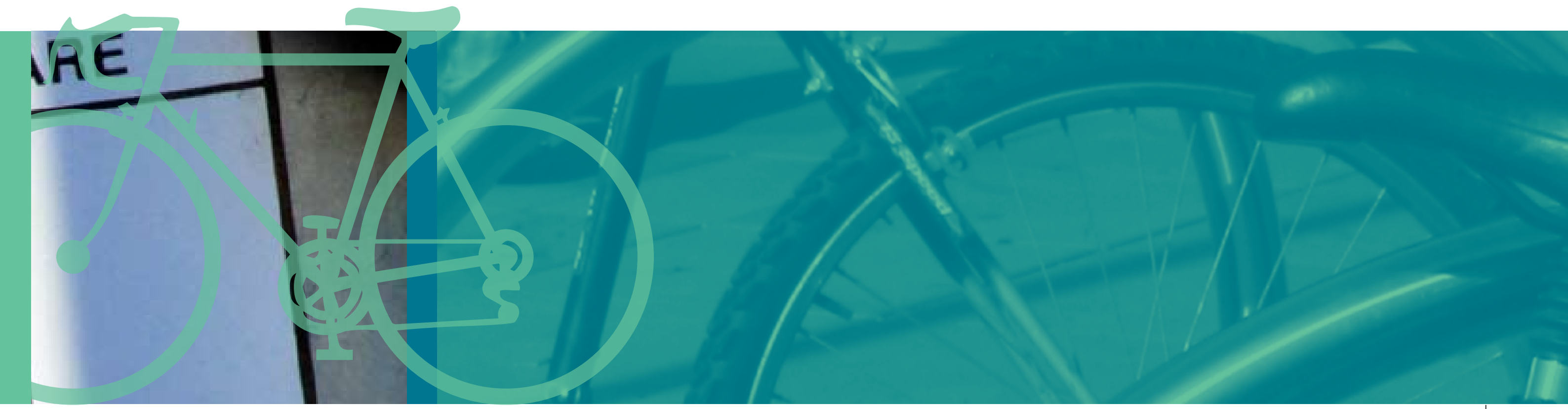
Overall, children walking to school are affected both by the distance to school and by their parents' perceptions of safety (which may be affected by physical improvements such as sidewalks but also traffic volumes, the media, etc.). While some perceptions are based in important realities, others may be altered by education and programming—this includes education for parents, for children, and for motorists

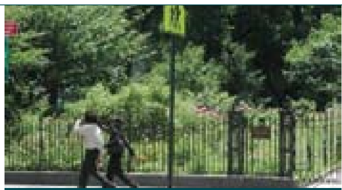
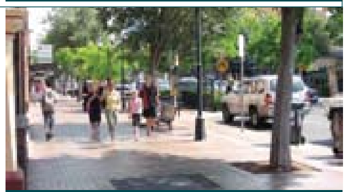
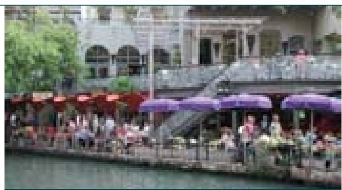
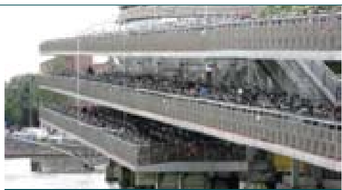
Figure 4: Facility types

SHARED FACILITIES WITH AUTOMOBILES

Type of facility	Representative photograph	
Roadways and neighbourhood streets	 Sendai, Japan	 Canberra, Australia
Traffic calming	 Taree, Australia	 Utrecht, Netherlands
Shared streets and bicycle boulevards	 Stockholm, Sweden	 Berkeley, U.S.
Wide curb lanes	 Tsukuba, Japan	 Vallingby, Sweden
On-street bicycle lanes—same direction as traffic	 Davis, U.S.	 Atlanta, U.S.

Type of facility	Representative photograph	
On-street bicycle lanes–counterflow	 London, U.K.	 Boulder, U.S.
Combined (shared) off-road facilities for NMT	 Izumi Park Town, Japan	 Minneapolis, U.S.
NMT MODE SPECIFIC FACILITIES		
Separated bicycle facilities	 Almere, Netherlands	 Kista, Sweden
Copenhagen bicycle lanes	 Copenhagen, Denmark	 Amsterdam, Netherlands



Type of facility	Representative photograph	
Bike boxes	 Utrecht, Netherlands	 Portland, U.S.
Footpaths or sidewalks exclusively for walking	 New York, U.S.	 Dubbo, Australia
Pedestrian only streets/paths	 San Antonio , U.S.	 Sydney, Australia
Bicycle parking/lockers	 Amsterdam, Netherlands	 Minneapolis, U.S.
Trip end facilities/stations for cycling (parking plus gear changing facilities, etc.)	 Himeji, Japan	 Milton Keynes, U.K.

Photographers: Ann Forsyth, Kevin Krizek, and Laura Baum.

CYCLING FINDINGS: A FOCUS ON SEPARATED BICYCLE FACILITIES (SBFs)

Given the range of populations (children and inexperienced to highly skilled) and infrastructure treatments (bicycle boulevard to on-street facilities to bicycle only off-street paths, see Figure 4 above), it is extremely difficult to arrive at similarly big picture conclusions, particularly regarding the impact of cycling-specific infrastructure treatments. Generally, discussions often turn to the merits of physically separating bicycle travel from other modes of travel versus right-of-way facilities that separate them via painting or striping or right-of-ways with little separation. We therefore broadly discuss the literature amidst various considerations, draw conclusions where able, and then turn to discussing other related matters and infrastructure treatments.

Figure 5: Cyclist on a "Copenhagen bike lane" on Swanston Street, Melbourne.

Separated bicycle facilities (SBFs) (also referred to as cycle tracks, mostly in the U.K.), including sidepaths, off-street bicycle paths, and sometimes Copenhagen bicycle lanes (named after the first known city to install one), are often used to reduce interactions between cyclists, pedestrians, and motor vehicles. Part of the difficulty in understanding the merits of SBFs stems from the varying definitions; generally speaking, they are defined as a path within the right-of-way designed specifically for cyclists and separated physically from motor vehicles. But even within this definition there is considerable variation. Physical separation may be in the form of bollards, raised paving, medians, vehicle parking or a completely different path, several meters from the road. The best known and widespread examples of SBFs come from the Netherlands and Denmark where such facilities are commonplace throughout many urban core areas as well as other environments.

Generally speaking, SBFs are usually installed with two key rationales: increased safety (preventing conflicts and collisions between modes) and increased use. The literature related to each is introduced in turn.

SEPARATED BICYCLING FACILITIES AND SAFETY

The most common argument in favour of SBFs stems from increased safety, which is ironic since SBFs as a safety measure is highly controversial and has even drawn point/counter-point arguments in leading transportation journals (Forester 2001; Pucher 2001).

Arguments opposed to cycling specific infrastructure cover several points, mostly relying on specific empirics. First among them stems from the cost required for their installation—a cost that research cannot reliably demonstrate is worth it. The cost figures to support such assertions are not always convincing, mainly because the benefits are so difficult to quantify.

A second argument against SBFs are empirics demonstrating how they are *not* necessarily safer, when considered vis-à-vis actual crash data. Opponents point to the fact that the majority of bicycle-auto conflicts are not from cars and bicycles travelling in the same direction. As information in Figure 6 suggests, the bulk of all bicycling oriented crashes are derived from intersections or turning movements. Separating the modes via infrastructure, many argue, exacerbates the complexity of intersections and hence leads to additional crashes and conflicts. A good number of studies suggest this.

For example, studying driver scanning behaviour in Helsinki, Summala *et al.* (1996) found that drivers making right turns looked to their left more often than their right, thus failing to notice cyclists on the adjacent bicycle path. Alternatively Räsänen and Summala (1998) in a study of bicycle-motor vehicle accidents in Finland, found that the most common accident type involved drivers turning right and a cyclist coming from the driver's right along a separated bicycle facility, a manoeuvre that has the cyclist coming from an unexpected direction. Furthermore, others suggest that cyclists in streets have fewer crashes. Pedler and Davies (2000) found that those cyclists who bicycled on the road had fewer interactions with motor vehicles at intersections than those who rode on the cycle tracks. However, this finding must be taken lightly, as the skill and confidence level of cycle track cyclists was probably lower than that of on-road riders. In a study of facility safety in Ottawa and Toronto, Canada, Aultman-Hall (2000, 10) found that "the rates of injuries indicates it is safest per kilometer for travel on the road, followed by off-road paths/trails and then least safe on sidewalks." Similarly, Wachtel and Lewiston (1994), in a study of bicycle-motor vehicle accidents in Palo Alto, California found that cyclists on sidewalks or bicycle paths incur a risk of collision with motor vehicles that is 1.8 times as great as that for roadway travel.

Figure 6: Bicycle Crashes

Most frequent car-bicycle crashes by age and urban versus rural

Urban	
CHILD	ADULT
1-Cyclist running stop sign	1-Motorist turning left
2-Cyclist exiting residential driveway	2-Traffic light changed too quickly
3-Cyclist riding on sidewalk turning to exit driveway	3-Motorist turning right
4-Cyclist on sidewalk hit by motorist exiting driveway	4-Motorist restarting from stop sign
5-Cyclist swerving left from curb lane	5-Motorist exiting commercial drive
Rural	
CHILD	ADULT
1-Cyclist exiting residential driveway	1-Motorist overtaking unseen cyclist
2-Cyclist swerving about on road	2-Motorist overtaking too closely
3-Cyclist swerving left	3-Motorist turning left
4-Cyclist entering road from sidewalk or shoulder	4-Motorist restarting from stop sign
5-Cyclist running stop sign	5-Cyclist swerving around obstruction

Source: adapted from Forester 1993, p. 269 (each category limited to top 5 frequencies)

Where safety research does not focus specifically on SBFs, it often addresses issues related to on-street bicycle lanes or wide curb lanes. In these cases, the available literature suggests the following. Harkey and Stewart (1997), in a study of 1,583 bicycle-motor vehicle interactions in 13 locations in six metropolitan areas in the U.S., found that bicycle lanes had the following advantages over wide curb lanes: (1) Motorists were less likely to encroach on the adjacent lane, (2) Motorists had less variation in their lane placement when passing, and (3) Cyclists were more likely to ride further away from the edge of the roadway. In addition, they found that bicycle lanes as narrow as 0.92 meters (3 ft) provide enough space for motorists and cyclists to interact safely, while bicycle lanes of 1.22 meters (4 ft) optimize safety conditions. Other research has supported the findings that vehicle encroachment into the adjacent lane is reduced (Hunter *et al.* 1999a, 2005; Hallett *et al.* 2006) and cyclist distance from the curb is increased (Hunter *et al.* 2005) on streets with bicycle lanes, as compared to wide curb lanes. Research focusing on the riding position of the cyclist found that cyclists rode, on average, further away from moving traffic where bicycle lanes were present and/or wider (Hallett *et al.* 2006). More general trends related to safety are discussed in the section, "Separated Bicycle Facilities: The Big Picture", below.

SEPARATED BICYCLING FACILITIES AND INCREASED USE

The other argument for SBFs stems from increased bicycle use, a claim equally as difficult to reliably document. We quickly review a sample of studies—from the specific to the more general. An inherent difficulty of this research comes when one examines detailed studies, particularly coming from the U.S., suggesting the relationships are highly nuanced. For example, research analysing 2000 census and other data from 43 large cities across the U.S. (Dill and Carr 2003) found that the number of bicycle lanes per square mile explains a large share of the variation in bicycle

commuting rates. Interestingly enough, however, the study differentiated between on-street and off-street facilities and the model with only on-street facilities was considerably more robust, suggesting that off-street facilities have a small (but still significant) role. Examining city specific studies, additional factors are accounted for in the explanatory models and thus, the reliability of these findings decreases.

Moudon *et al.* (2005) surveyed 608 randomly sampled respondents in urbanized King County, Washington (U.S.) and found that proximity to trails (separate bicycle facilities) and the presence of agglomerations of offices, clinics/hospitals, and fast food restaurants were significant environmental variables in respondents cycling at least once per week. Conversely, variables that were theorized to be significant, but were not, included the presence of (on-street) bicycle lanes, traffic speed and volume, slope, block size, and the presence of parks. These findings somewhat comport with Krizek and Johnson (2006) who found that only close distances to SBFs were statistically significant predictors of choosing cycling, though the relationship was not found to be linear nor even statistically significant at further distances. A key point from this sampling of studies is that most conclusions are drawn from cross-sectional studies that control for a minimum number of factors. The more disaggregate the unit of analysis, the muddier the water becomes. Additional confounding issues stemming from self-selection trouble the ability to arrive at reliable conclusions regarding the merits of such facilities.

But rather than simply approach the issue as one correlating use with proximity to facilities, the causal mechanism may be less direct. Increased use may be related to the dimension discussed above, safety, but more at a perceptual level for the user (rather than actual level). A logical stream of thought emerging from the literature runs along the following lines. It is asking a lot for all cyclists, particularly young, old, or inexperienced, to ride amidst vehicular traffic (even with law abiding and highly educated motorists). SBFs provide increased choice. This choice may be attractive for select populations and others, particularly from a safety standpoint. Whereas the above section focused on safety empirics, an equally compelling argument is how they relate to perceived safety (whether such safety is real or perceived, however, is another question).

For many, perception is reality and in this case, SBFs usually win out. For example, on-street facilities elicit varying reactions from cyclists. In a survey of members of the Texas Bicycle Coalition, Taylor and Mahmassani (1996) found that bicycle lanes were a stronger incentive for casual and inexperienced cyclists to ride than wide curb lanes, but for experienced cyclists there was no preference for either facility. Landis *et al.* (1997) found that, all else being equal, cyclists perceive streets with bicycle lane striping or paved shoulders as safer than those without. Many psychologists and researchers argue that perceived safety is all that matters and this has been supported in some applications.

The closest stream of research that addresses perceived safety comes under the banner of bicycle level of service (LOS) models which aim to provide a common rating system for facilities used by cyclists. Models are typically developed using data from cyclists on their perceived safety and comfort when riding in different environments. Landis and colleagues have conducted a number of studies on bicycle LOS for different facilities—often SBFs are addressed in such applications. Where SBFs are not directly addressed, many of the tenets that SBFs aim to shield cyclists from (e.g., autos, fast moving traffic) are considered.

In a study describing a generalized urban bicycle LOS model, Landis *et al.* (1997) highlight the significance of bicycle lane striping and road condition on cyclists' perceptions of safety. Landis *et al.* (2003) later found that traffic volume, width of the outside through lane, and intersection crossing distance are the key elements affecting intersection LOS for cyclists. In another study, the following factors were found to be significant for urban arterials: traffic volume, number of through lanes, speed limit, percentage of heavy vehicles, surface condition, width of outside lane, and the number of unsignalised intersections (Landis *et al.* 2006). For off-street shared-use paths, Hummer *et al.* (2005) found that path width, presence of other users, and presence of a centreline significantly affected ratings of trail experience, with both centrelines and other users lowering ratings, while path width raised them. Studying a variety of intersections where cycling facilities end (discontinuities), Krizek and Roland (2005) show that cyclists' discomfort is related to increased distance of crossing intersections, having parking after the discontinuities, and wider width of the curb lane. Given that some research indicates that SBFs lead to increased perception of safety by a variety of users, an expected outcome is increased cycling.

The most convincing evidence showing that SBFs result in heightened use comes from relatively large scale studies focusing on the Netherlands, Denmark, and parts of Germany. Reportedly, from the mid-1970s to the mid-1990s, SBFs expanded greatly in all three countries. In Germany, the bikeway network more than doubled in length, from 12,911 kilometers in 1976 to 31,236 kilometers in 1996 (German Federal Ministry of Transport 1998). In the Netherlands, the bikeway network doubled in length, from 9,282 kilometers in 1978 to 18,948 kilometers in 1996 (Pucher and Dijkstra 2000; Statistics Netherlands 1999). The onset of facilities was accompanied by a general upturn in the amount of cycling as well—though these rates were already notoriously high relative to most other cities in the world. These claims and

observations hold much value, though at the same time, one must take into account the power of complementing SBFs with more general and widespread adoption in cycling-oriented policies (Pucher and Buehler 2006; Ministerie van Verkeer en Waterstaat 2007).

SEPARATED BICYCLING FACILITIES: THE BIG PICTURE

Clearly there are a number of factors to consider in planning for both SBFs and other on-street facilities. A poorly designed separated facility (e.g., next to a sidewalk or with inadequate attention devoted to intersections) is indeed likely to be more dangerous than riding on the roadway. Equally, a rail-trail with grade-separated intersections, easy grades and a 12-foot paved surface is likely going to be a great alternative to a parallel busy arterial street with no space for bicyclists.

The available literature, unfortunately, does not allow one to draw direct correlations between SBFs and increased safety. Nor can we draw direct correlations between SBFs and increased use. It is extremely difficult to make more definite conclusions because studies have too seldom controlled sufficiently for confounding factors. For example, some studies have considered off-street facilities to include bicycle facilities and sidewalks. Alternatively, other studies have not controlled for skill and confidence level of the cyclist.

Figure 7: Example of bicycle boxes in downtown Melbourne. A discussion about these facilities is found below.

There is, however, general consensus on the following. The belief that SBFs reduce the risk of accident is a common reason SBFs lead to increased perception of safety for cyclists across different types of users. With increased perception of safety comes increased ridership. And, in locations with higher levels of ridership, there is convincing evidence that, per capita, the cycling is safer because of a concept referred to as *safety in numbers*.

Conventional wisdom suggests that the number of collisions varies directly with the amount of walking and bicycling. However, upon examining detailed data from a variety of settings—68 cities in California (U.S.), 14 cities in Europe, 47 towns in Denmark, and eight European counties—findings revealed the same picture: a non-linear relationship, such that collision rates declined with increases in the numbers of people walking or bicycling (Jacobsen 2003). This means that motorists are less likely to collide with a cyclist bicycling if more people walk or bicycle and initiatives to encourage increased rates of cycling may be an appropriate strategy to increase overall safety as well.

The most reliable conclusion, therefore, drawn from the available literature about the efficacy of SBFs and related bicycle treatments requires roundabout, though sound, reasoning. SBFs, however they are defined or implemented, usually lead to increased perception of safety across a wider array of users which helps induce bicycle use. Communities with higher rates of bicycle use have fewer crashes with motorists on a per capita basis and are therefore considered safer.

INNOVATIVE CROSSING TREATMENTS

In any environment for bicycle movement, intersections are particularly problematic. Clearly delineated SBFs fail to improve such problems. This draws our attention to various intersection treatments and we highlight below some themes where, unfortunately, only minimal study has been completed.

Bicycle boxes

The bicycle box (or advanced stop bar) is a treatment aimed to reduce conflicts between turning vehicles, forward moving vehicles, and forward moving cyclists (see Figure 7). The box is a right angle extension of a bicycle lane that allows cyclists to get ahead of automobiles stopped at a traffic light. When the light turns green, cyclists are able to move more safely through the intersection ahead of the autos. In more

Figure 8: Innovative Crossing Treatments in Muenster

Figure 9: Coloured treatment for a bicycle lane outside of Flinders St. Station, leading into downtown Melbourne.

progressive environments, cyclists have their own signal, which turns green prior to the autos' signal to give a further head start.

Little research has been done on the usage or safety of bicycle boxes, though one study by Hunter (2000b) examined the effects of the installation of a bicycle box in Eugene, Oregon (U.S.). The author found that 22 percent of cyclists with the opportunity to do so used the bicycle box. While conflicts between cyclists and vehicles in the intersection did not change following installation, no conflicts were observed involving cyclists who used the bicycle box as intended.

These kinds of innovative crossing treatments may well take some getting used to on the part of cyclists and motorists before definitive results on their effectiveness can be seen. Considering the safety issues that exist, intersections are an important focal point in planning for cyclists and pedestrians. However, by themselves, they have limited capacity without regard to the larger network of facilities.

Many European countries use coloured treatments to demarcate space for bicyclists (and sometimes pedestrians) and to draw motorists' attention to various facilities (Denmark – blue; the Netherlands and Germany - red, U.K. - red or green, France, Australia, New Zealand – green). Such applications are usually at intersections but may often parallel heavily travelled routes leading up to high trafficked areas.

The most notable application of the use of coloured treatments by a municipality formerly with no coloured treatments comes from Portland, Oregon (U.S.). The city striped select conflict points (usually heavy right turning traffic crossing the path of straight-ahead bicyclists) with blue markings and appropriate signing. The few studies that evaluated the impacts of the colour striping found that motorists were more likely to yield to cyclists after installation; however, the change also resulted in fewer cyclists scanning for motorists or using hand signals to indicate intent (Hunter *et al.* 2000). While the majority of cyclists and a near majority of motorists reported that the lanes enhanced safety, there is some question as to whether the increased comfort level of cyclists could lead to additional conflicts or collisions. Gårder *et al.* (1998) studied the effects of installing raised and painted bicycle crossings through intersections in Gothenburg, Sweden. They found an overall cyclist risk reduction of approximately 30 percent, due to both the new crossing and the increase in total cyclists using the crossing. However, the authors point out that cyclist speed plays a large role in collisions and that changes that increase cyclist speed (such as safer crossings) may pose a significant safety danger for all users.

Other than the facilities on which NMT takes place (trails, roads, intersections), there are other infrastructure important to consider—particularly for cycling—such as the availability of parking facilities, showers, and lighting. However, there is too little study of this infrastructure to allow for a robust account to understand the importance of each.

BICYCLE LOAN PROGRAMS

A final form of hard infrastructure strategy—in the sense that it involves metering equipment, parking areas and such—is a bicycle loan program. Bicycle loan programs appear in all shapes and sizes in cities throughout the world and more recently, are the latest fad in this line of work. The central concept of these programs is making available free (or nearly free) access to bicycles for local transportation needs. Variables at play include primary audience (tourists or locals or both), length of rental, to charge or not to charge, membership requirements, etc. Several variations of this concept have been explored over the past dozen or so years—few with any notable success. Theft and maintenance are consistent issues.

The latest fashion of these efforts include several European cities (the French cities of Lyon and Paris as well as London, Barcelona, and Stockholm), which have signed contracts with private advertising agencies that supply the city with thousands of bicycles free of charge. In return, the agencies advertise both on the bicycles themselves and on other select locations in the city. These programs also prevent theft by requiring users to pre-purchase user cards with credit cards and by equipping the bicycle with complex anti-theft and bicycle maintenance sensors. In the case of not returning the bicycle within a day, the bicycle sharing operator is allowed to withdraw money from the given credit card account.

Detailed, systematic, and robust studies of community bicycle programs are difficult to come by. Recent reports optimistically suggest positive impacts. For example, the programs instituted on grand scales in Lyon and Paris have received rave reviews in the popular press; anecdotal evidence suggests the “loaner” bicycles are widely used. The little research that exists on these programs is less optimistic regarding the potential impact of bicycle sharing on reducing auto trips, though findings may be highly case-specific. One study by Noland and Ishaque (2006) surveyed users of the OYBike program in London and found that bicycles were primarily used for leisure and recreation trips and that repeat usage of bicycles was not high. Results suggest that the primary barriers to usage were uncertainty about bicycle condition, difficulty with the locking system, and the need to use a mobile phone to check out a bicycle, factors which need not be inherent to bicycle sharing programs generally. In a case study report without empirical validation, DiDonato *et al.* (2002) report that the majority of trips made using bicycle-share bicycles replace walking or transit trips, and therefore do not contribute to a reduction in overall auto use.

MOTORIZED TRANSPORTATION USING PEDESTRIAN AND CYCLING FACILITIES

Finally, while not a focus of this review, intended to focus on existing research related to non-motorized transportation, we note that in addition to cyclists and pedestrians a variety of motorized modes of transportation also use pedestrian and cycling facilities (e.g., Segways, gophers, motorized wheelchairs, electric bicycles, and even small motor scooters). Use of such machinery does not likely affect travel walking; however, as numerous guidelines and prescriptions related to width of path indicate, such modes may well require wider and more level sidewalks, and possibly better lighting, than pedestrians alone.

If pedestrian infrastructure is provided that is adequate for such machinery, as equity reasons suggest it should, such infrastructure will be more than adequate for pedestrians in terms of width, evenness, and texture. That is, a more than adequate level of pedestrian infrastructure is likely to be provided for equity reasons to support such modes (though this will not necessarily lead to pedestrian-supportive community design). Of course, pedestrians are likely to appreciate such features as shade as well but shade trees may well be provided for other environmental reasons. Overall, pedestrians can benefit from infrastructure provided at a quality needed for other purposes. We deal with this issue of the benefits of redundant provision later in the report.

While off-street cycling facilities will likely have adequate size and grade, these motorized modes may move more slowly than Class A cyclists, thus creating issues related to compatibility. However, in terms of this potential for conflict with cyclists, there is not a great deal of literature specific to these motorized modes.

SUMMARY

3.1 Community or urban design including gross population density, street pattern, and accessible destinations are important in creating a walkable environment.

3.2 While distance is very important for pedestrians, on average they will walk further than the anecdotal rule of thumb of 400 meters used in many planning applications.

3.3. The relationship between pedestrian infrastructure (particularly sidewalks) and walking is complicated. There are many reasons to provide such facilities and, if designed to be adequate for such motorized equipment as gophers and Segways, they will likely be adequate for pedestrians.

3.4 Perception of infrastructure is important in walking but it is not clearly related to actual provision. That is providing more infrastructure may not in itself change perceptions. It is important to understand better how marketing and educational programs can be used to modify people's perceptions of walkability.

3.5 Separated bicycle facilities are particularly troublesome in intersections involving automobile traffic and do not necessarily appear to be safer.

3.6 Separated bicycle facilities and related treatments lead to the perception of increased safety on behalf of the many cyclists.

3.7 Intersections are critical pinch points for cyclists and detailed treatments increase cyclists' comfort in navigating them.

3.8 Bicycle loan programs may have an impact in or close to urban core areas, where they are usually available, though scant evaluation precludes any conclusions at this point.

SECTION 4: ROLE OF PREFERENCES

SELF-SELECTION

The bulk of existing research on NMT—if not all of it—responds to research questions using cross sectional data (i.e. data at one point in time). The urban planning community is learning, not surprisingly, that things are not as simple as some of these cross sectional studies might indicate. Analysing a single policy or environmental change without fully capturing other important influences may lead to errant conclusions. Such factors hold particularly true for matters related to understanding the factors leading to people's decision to cycle. Trying to unravel such decision-making by isolating the specific role of various facilities, for example, is a complex endeavour.

Put another way—as any reliable textbook on statistics suggests—correlation does not mean causation. It is important to distinguish between the following: (a) documenting correlations between bicycle facilities and use, versus (b) claiming that bicycle facilities will induce use. The majority of previous work on the subject has not adequately differentiated between the two. For example, residents (or families) often select locations to match their desires for certain behaviours, such as walking or cycling. This is an option they prioritize in their home and work location. This suggests that differences in rates of NMT between households in different areas of the city with different access to NMT facilities should not be credited to facility alone; the differences may well reflect self-selection. In other words, people who are likely to cycle, choose to locate in a given neighbourhood or employment area where they have a better chance of cycling.

The above considerations are particularly vexing for researchers aiming to shed light on debates and discussions around causality. Proving statistical association is not the same as proving causality. Two phenomena can move together due to chance, or there could be bi-directional causality. There is no statistical test for causality. What is the researcher of cycling and walking behaviour left to do? How can one reliably say that cycling facilities will increase levels of cycling and walking? It is difficult.

These considerations suggest that differences in travel between households with different neighbourhood design should *not* be solely credited to various interventions that apply to the community. In other words, people who are likely to walk anywhere, choose the choice to locate in a given neighbourhood where they have a better chance of walking or cycling. Alternatively, populations might be engaging in walking or cycling behaviour—if for no other reason—than the willingness to advance health. It may have little to do with hard or soft measures. This makes incorporating walking into models of transportation more complex, as a walk "trip" may also be a recreational activity.

Suburban residents also tend to express more dependence on their cars and also to think travelling by car is safer than walking, biking, or taking transit. Most significantly, in some studies suburban residents put more importance on safety than do residents of traditional neighbourhoods, who put somewhat more importance on sociability and attractiveness (Handy *et al.* 2006). Are these differences in attitudes and preferences more important in explaining travel behaviour than differences in the built environment, thus supporting the self-selection hypothesis? This is the million dollar question that much research is aiming to answer (e.g., Cao *et al.* 2006b).

SUMMARY

4.1 Planners should not underestimate the important role that predetermined preferences and lifestyles play in understanding rates of NMT. In some environments and for some populations, preferences may undermine the role that other initiatives—programming or infrastructure—may have.

SECTION 5: ACCOUNTING FOR AND MODELLING NON-MOTORIZED TRAVEL (NMT)

Accounting for and modelling NMT proves to be very difficult because of a range of factors related to data availability: learning of behaviours, representing them along networks, and using units of analysis and simulation strategies precise enough to detect noticeable differences. We comment on each below.

A basic foundation of NMT research—knowing the various behaviours of individuals—continues to be a major hurdle. Most available information on NMT addresses the number of people who walk or cycle, as opposed to number of trips or miles travelled. The existing surveys and other sources that address the frequency of NMT produce a wide variety of results. Each source asks about a different time frame; the number of people who complete the behaviour on a bicycle in a week will be larger than the number who ride in a day.

In terms of measurement, NMT behaviour can be ascertained by (a) self report (e.g., diary, survey), (b) observation (in person, using sensors) or (c) via various motion detectors (accelerometers, pedometers, global position systems, etc.) (Troiano 2005). There is significant work testing the relative reliability and validity of these approaches. Figure 10 captures some of the differences across these measures (Troped 2001; Krizek *et al.* 2007b).

More specifically self-report has problems with definitions (what is a trip—does it include walking to the bus, walking the dog) and, because NMT is a virtuous behaviour, people want to win the researchers' approval by showing that they engage in these activities. However, because many walk trips are short and chained with other trips they are easy to forget e.g., walking to transit or from a parked car around a shopping centre. Furthermore, a key issue for walking is that one trip can serve multiple purposes—e.g., travel and health—which is difficult to deal with in models.

These are difficult problems to address. The data necessary to reliably build such models is in short supply for walking and cycling. User and trip characteristics at a suitable level of aggregation, along with user preferences for facility design characteristics are currently of limited quality and are considered a high priority for improvement (USDOT 2000). These data items are not adequately covered in most large scale survey instruments, such as metropolitan travel surveys or the Nationwide Personal Transportation Survey (NPTS) in the U.S. and where they do, there are problems. As Krizek

Figure 10. Measurement Strategies and How Well the Behaviour is Captured

Measurement strategies	Phenomena / Behaviour to Measure: Who does and does not walk or cycle	Number of trips	Distance	Purpose or destination	Intensity
Self-report	+	✓	–	+	–
Observation	–	+	–	–	✓
Instrumentation	+	✓	+	–	+*

\+ = is good at capturing this phenomenon/behaviour
✓ = fair
– = poor
* the ability to measure intensity differs from accelerometers (good) to GPS units (poor)

Source: Krizek et al. 2007b.

et al. (2007b) explain:

> For this reason, the recent version of the U.S. National Household Travel Survey (NHTS) made a special effort to prompt respondents about walking and bicycle trips using a follow-up telephone questionnaire. Interviewers asked, "Did [you] use any other type of transportation during [your] stay in [city here], including bicycling and walking?" So far, I have recorded [N] trip(s). Before we continue, did [you] take any other walks, bicycle rides, or drives on [trip date]? Please include any other trips where [you] started and ended in the same place." Walking trips increased significantly between the 1995 NPTS and the 2001 NHTS, and survey administrators believe this increase is attributable to the improved prompts rather than a true increase. Also of concern is the period of time covered by the diary: a one-day diary may miss occasional use of walking and bicycling as a mode of transportation and as a form of exercise or recreation (Krizek *et al.* 2007b).

While at first blush it may seem that instrumentation would be more accurate, in fact such methods do have weaknesses – e.g., motion detectors do not indicate purpose and people forget to wear them; GPS units do not work in some locations and do not measure intensity of activity; sensors only count people using facilities, ignoring those who are not active. Many of these detectors are also expensive and/or bulky and the fields lack standard protocols for processing information.

Such issues often result in analysts borrowing assumptions from analysis usually slated for other purposes. A common example is an analysis that borrows impedance values (relative time, distance, or cost) from a locally calibrated travel model. The values extracted from these data may be sensitive to the environment in which they were collected. Ideally, travel survey data would be collected year round and cover all seasons (Ortuzar and Willumsen 2001). More commonly, data are collected over a period of several months and reflect weather conditions prevailing at the time the survey data were collected.

This is especially important in the case of non-motorized modes and in locations where significant seasonal climate variations exist. For example, if survey data are collected during warmer, drier months it is possible that changes in travel behaviour during colder or more precipitous months might be missed. These changes might include mode shifts, in which case the number of pedestrians and bicyclists might be overestimated during cold weather periods, and changes in destination choice for discretionary trips, which would affect the length or distance of travel, and hence the relevant impedance values.

Furthermore, a key distinction related to cycling that has to be tracked is that adults are considerably less likely to ride a bicycle than are children, regardless of the time frame being considered. These two groups must be studied separately to avoid confusion or ambiguity. This is generally not an issue with most bicycling surveys, which tend to focus on adults. It is, however, a factor in deriving numbers from general travel data collection surveys that deal with the entire household.

But NMT research is more than about just learning of the behaviours. It also requires data on the context, requiring multiple data sets relating to travel behaviour and land use, each of which presents unique challenges for analysts addressing NMT.

LAND USE/URBAN FORM DATA

The quality of land use and urban form data directly affects the accuracy of NMT research. Extending the range of desired destinations beyond employment and improving the accuracy or robustness of accessibility calculations requires data at a spatial resolution that is not typically available in most research applications. There are sources of establishment-level data on attributes such as employment, sales and other variables that could potentially serve as good proxy variables for attractiveness and be easily scaled to different levels of geographic aggregation. However, these sources are typically private financial organisations or highly confidential. The data can be costly to acquire and require significant effort in terms of cleaning and preparation for spatial analytical use (Forsyth *et al.* 2006). Alternate, low-cost sources of data such as business directory telephone listings have been employed elsewhere (Handy and Clifton 2001) in the context of the calculation of measures of "neighbourhood" accessibility, though these data sets typically contain limited information on size or quality of establishments. While there have been few standard approaches to constructing NMT related environmental variables, recent work in public health has developed protocols for environmental measurement that can provide models for such work (Forsyth 2007a 2007b).

ZONAL STRUCTURE AND NETWORKS

In addition, other efforts often use zones as units of analysis that do little justice to the detailed nature of pedestrian travel. For example, they may aggregate information to census tracts (in the United States, approximately 5,000-6,000 people), zip or postal code areas, or transportation analysis zones (TAZs). An ecological fallacy arises because average demographic or urban form characteristics are assumed to apply to any given individual neighbourhood resident. When measures of commercial intensity are aggregated, for example, each zone reveals the same measure despite each zone exhibiting considerably different development patterns. The heart of the problem—and the ability to detect such subtle geographical differences—lies with the size of the units of analysis that are employed (Iacono *et al.* 2007).

Networks employed for purposes of regional travel models typically

replicate roadways. Networks for walking and cycling are often different and need to be drawn at a finer scale. Specifically, the network structure is too coarse to trace the paths chosen by pedestrians and cyclists, and the zones are too large to differentiate many of the shorter trips made by bicycle and on foot. Also, few networks contain links with specialized facilities for non-motorized travel, such as sidewalks or SBFs, and on-street bicycle lanes.

One way around these problems, as will be described in greater detail in a later section, is to use street network layers encoded as geographic information system (GIS) files as the basis for calculations of a minimum-cost path (with distance as a proxy measure for cost) between an origin and destination point. These networks can be manually modified to include certain types of special facilities. However, few cities or regional authorities have complete inventories of NMT systems, making the construction of a complete pedestrian and bicycle network a resource-intensive task. If time is the desired impedance measure, then assumptions need to be made about the relationship between distance and time in terms of an average speed. While this may be acceptable for pedestrian travel, the availability of bicycle facilities may alter bicyclists' travel time, necessitating special treatment of these facilities (El-Geneidy *et al.* 2007).

INADEQUATE MODELS

Related to the issue of inadequate networks and data is the applicability of model components (most commonly the well-used four-step transportation planning models) to appropriately represent NMT. Most relevant to several components of any urban modelling system is how accessibility is represented and the specific impedance function used, representing the influence of travel time, money and other costs on the willingness of individuals to travel longer distances. In transportation planning practice, it has been common to use gravity or other synthetic models to forecast the spatial distribution of trips, from which an impedance value can be estimated. While this approach works reasonably well for motorized modes, which tend to have a more regional distribution, there are often a large number of origin-destination pairs with zero observations. This problem, known as the sparse matrix problem, is exacerbated by the application of such models to origin-destination data for non-motorized modes, which tend to have a more concentrated spatial distribution (Iacono *et al.* 2007).

It is only the combination of the above and detailed efforts—measuring patterns of use, networks, attractors—that will allow robust modelling efforts that can then be used to more reliably predict induced demand (see for example, Lindsey *et al.* 2006).

SUMMARY

5.1 NMT planning efforts could be substantially enhanced with greater information about NMT travel; this includes data collection efforts specifically geared toward better understanding the range, purpose, and impediments for walking and bicycling.

5.2 To best understand NMT travel analysts require relatively small geographical units of analysis and detailed data about such environments (e.g., destinations as well as networks).

SECTION 6: CONCLUSIONS AND FURTHER RESEARCH

Available literature on NMT is in ample supply. It would therefore seem that we could say more with certainty. Unfortunately, this is not the case; several complex factors interfere with our ability to draw general conclusions about the impact of various interventions, be they hard or soft.

This concluding section summarizes and synthesizes the above review into several take away points. The section is divided into three parts:

- Conclusions derived from a close reading of available literature,
- Conclusions informed by both the literature but also based on professional experience, and
- Fruitful areas for future research.

CONCLUSIONS BASED EXCLUSIVELY ON AVAILABLE LITERATURE

Learning about walking and cycling is extremely difficult

Walking and cycling remain understudied phenomena, particularly when researched in a rigorous manner. To increase the knowledge of how users respond to various interventions, more data must be systematically collected in a variety of environments and credibly analysed. Research needs to do the best it can to isolate confounding factors such as psychological, social, and economic factors. Because of these limitations in fully understanding NMT and how it is affected by various policy and infrastructure investments, planners and politicians must be careful not to overestimate the likely impacts of various treatments.

There is no silver bullet

It needs to be recognized that no single infrastructure investment will have dramatic changes; there is no silver bullet, especially when considering the complexity of NMT. Yearning for such will only lead to frustrating dialogue; time and resources should best be spend in a more constructive manner.

Necessary versus sufficient conditions

Understanding that there is no single bullet, it is important to recognize that there are instances where certain pieces of the puzzle must be in place to even allow NMT to occur. We refer to these as necessary conditions. For walking, for instance, good community design stands out. Lacking tolerable distances for walking between common origins and destinations, few people will walk, regardless of how attractive the environment is. In some specialized environments, a similar assertion could be made about the role of SBFs—e.g., in corridors with high levels of fast moving auto traffic.

Combined strategies work

It is only natural—and expected—for policy makers and infrastructure professionals to want to know the measurable impact a given infrastructure investment will have (what will be the effect of various intersection treatments, how many more cyclists will be induced by constructing a path, will an on-street bicycle path make a difference?).

However, several factors combine to produce a successful walking or cycling environment and ultimately make it attractive for people to bicycle or walk. For example, consider the age-old question: what factors best explain the variation among municipalities in NMT use and what role does policy and (wider) traffic policy play? The most robust studies suggest it may well be that any particular feature contributes only a little, and then only for those with some psychological, social, or economic predisposition to walk or cycle. Communities with notably high rates of cycling use many different strategies—programming, policy, environmental design, and other. Walking is not so dependent on unusual infrastructure but still significantly benefits from a multi-pronged approach that reflects the needs of different user groups.

More specifically, non-infrastructure modifications may include traffic calming of residential neighbourhoods, restrictions on motor vehicle use, better traffic education of both motorists and non-motorists, and enforcement of traffic regulations protecting cyclists. Coordinated implementation of multi-faceted and mutually reinforcing policies and programs is needed in order to create successful pedestrian and cycling environments.

Role of key destinations and design features in walking

Walkers are sensitive to distance, so the location of destinations would seem to matter a great deal to this group. However, findings from recent research on destinations or mixed use have not been as clear as many assumed it might be, as is explained in Section 3.

The following findings can be synthesised:

- Overall density, which is related to the clustering of destinations including other housing units, is associated with travel walking in most, but not all, studies.
- Specific destinations are seen as important in various studies but the destinations differ between studies.
- Street patterns are important in some studies and not others—this may be a measurement issue or it may be due to the use of space (for instance in suburban areas pedestrians may cut through large blocks on paths not identified in the data collection nor known in most network measures).
- Infrastructure has some importance in travel walking—sidewalks, lighting—but merely building a sidewalk will not make an environment walkable.

However, these features do combine to create a walkable environment.

Target specific populations

Assessing the effect of different treatments is on surer footing when specific populations are targeted; certain populations comprise low hanging fruit because they are likely to be more receptive than other populations. We describe several populations and how and why their behaviour may be more responsive to walking or cycling improvements or interventions.

- Recent movers: These populations are seen as open to changing travel mode. However, studies of soft measures such as education and counselling have found them difficult to recruit (Department of Transport 2005; Ampt *et al.* 2006).
- Low income people including students: People with low incomes have been consistently found to be more sensitive to pricing of modes. For those without constraints such as complex trip chaining to reach child care or distant work, non-motorized travel can be cost effective.
- Others with lower proportions of driver's licenses (youth, seniors) are also potential targets for both hard and soft interventions.

Given these factors, cycling prompts a conundrum of sorts. Bicycles are relatively inexpensive modes of transport (though not quite as cheap as walking). In this respect, getting people on bicycles opens up both mobility and accessibility to populations; and, enhanced bicycle facilities may play an important role in such.

As pointed out, primary populations who stand to benefit are those who may be at a disadvantage in terms of auto-ownership or operation, such as the young, the elderly, the economically disadvantaged or more generally, unlicensed populations. In areas rich with these populations, the provision of free bicycles or enhanced facilities may have greater impact. For example, student populations and university towns (Baltes 1996) are notoriously associated with high levels of cycling (e.g., Stuttgart, Germany; Muenster, Germany; Gronigen, the Netherlands, Davis, California (U.S.); Boulder, Colorado (U.S.)). Enhanced facilities in these environments will be heavily used because there are more people engaged in the activity.

Outside of college towns, however, at least in the U.S., the predominant cyclist appears to have few of the aforementioned characteristics. The average cyclist is male, white, higher income, and between the ages of 18 and 44. While in Europe and Asia cyclists are more diverse, the environment and policy context in Australia has enough similarities with the U.S. to require close consideration. Data from a supplemental survey in Queensland by the Australian Bureau of Statistics showed that three quarters of cyclists (people who had cycled in the last year) were aged 15-44, 60 percent were males, male cyclists were more likely to ride each day than females (almost 11 percent versus 4.5 percent) and most cycled for recreation or exercise (Australian Bureau of Statistics 2004).

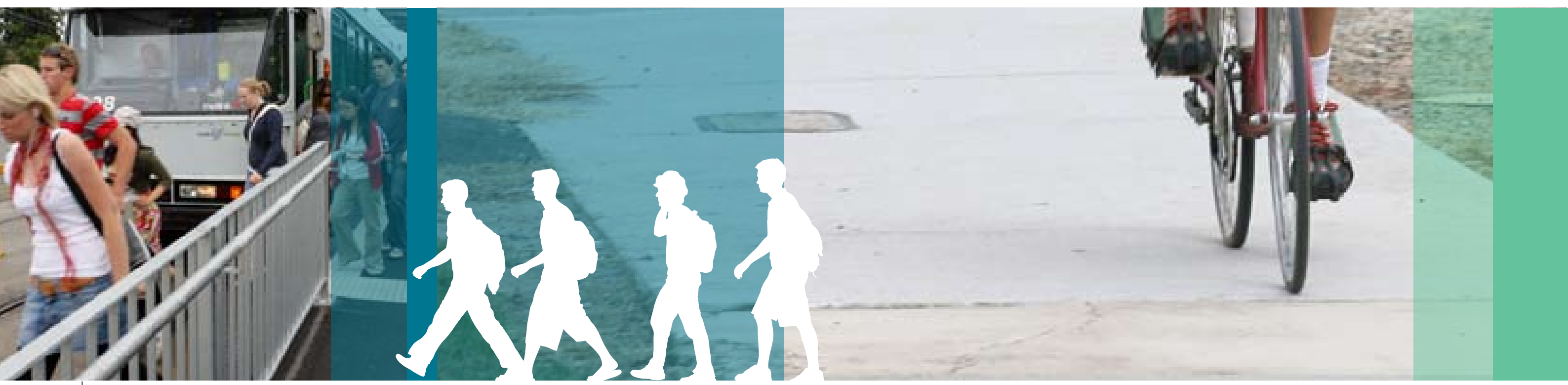
What does this mean and what are the planning implications based on some of the above described conclusions? First, where there are real needs and concerns to address young, old or sometimes female populations, it suggests that SBFs have a pronounced role because they are perceived as safer. For the young, limited experience and unpredictable movements put children at special risk on streets. Cycling specific infrastructure is more important for those with slower reflexes, frailty, and deteriorating hearing and eyesight. Furthermore, women have been shown to be more risk averse than men when it comes to cycling facilities (Krizek *et al.* 2005). For pedestrians, this indicates populations where marketing may be useful.

Policy levers or strategies

The above conclusions can best be summarized by Table 1 in the summary at the beginning of this report showing five different classes of policy levers or strategies used to promote NMT (we also include a fifth category: combined strategies). Dark shading indicates more important; lighter shading indicates less important. Based on a close reading of the literature, the efficacy of each policy lever differs by mode and some strategies, such as programming, have extremely little evaluation (thus the absence of any shading). Digesting the available literature, it is clear that tenets of community design (e.g., having origins and destinations close to one another, street design) is paramount for transportation related walking. For cycling, ensuring a higher level of perceived safety is important because this leads to more use and thereafter, lower levels of cycling-auto crashes per capita.

The hope of many infrastructure agencies is that specific infrastructure investments will

Figure 11: Facilities along St. Kilda Road, Melbourne showing redundancy is fine and sometimes necessary



increase NMT. For walking, infrastructure is less important and overall design more crucial given the sensitivity of pedestrians to distance. Sidewalks are significant in some studies and not in others. Perhaps, basic provision on major roads provides a basis for walking and improvements to quality do not improve that. However, it can be said that the sidewalk to nowhere will be little travelled. Findings are even less strong for such features as street lamps and street trees although this may be due to lack of variation in provision—if there is lighting and some street trees along almost every sidewalk small variations such as providing decorative fixtures may not make much measurable difference (Forsyth *et al.* 2008).

CONCLUSIONS INFORMED BY LITERATURE BUT ALSO BASED ON PROFESSIONAL EXPERIENCE

The walkable place

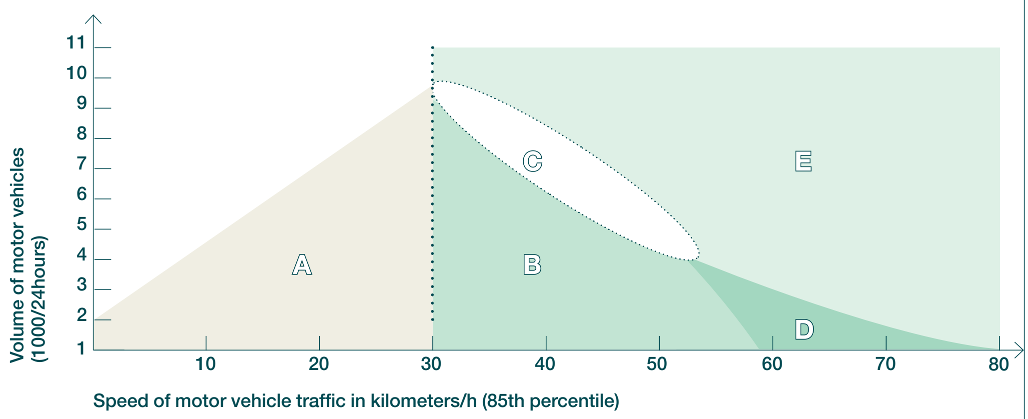
Creating a convenient environment where people have the option to walk is a good thing—at the very least it provides choices. While overall community or urban design is vital in creating walkable distances, pedestrian infrastructure has many benefits. Increased numbers of street trees can be justified for reasons of shade, temperature control, aesthetics, habitat, and so on. Continuous pedestrian routes are useful for providing choices for those who choose not to drive or cannot.

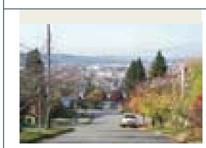
What type of cycling facilities where?

Given the range of infrastructure options, an outstanding question in many discussions is how one can best know what treatment should be applied to different environments. Available research can provide only broad suggestions regarding the applicability of various treatments and their merits. Synthesizing central themes from various studies and scenarios, professionals concerned with bicycle infrastructure have struggled with such general guidelines. Practice in the Netherlands is reportedly informed by using a schematic from which Figure 12 below is adapted; it prescribes different suggested treatments depending on traffic volumes and vehicle speeds.

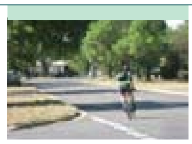
Of course, not all treatments are possible in each desired circumstance due to limitations of funding, available space or other issues. For this reason, corridors might require a range of treatments, sometimes a handful of different facility types along a short stretch. A key point in Figure 12 is that it is important to acknowledge that there are environments where SBFs may be unnecessary. These conditions include (1) residential streets, (2) where there is an incapacity to maintain them (e.g., sweeping), and (3) where a municipality cannot commit to "no parking" regulations. Notwithstanding the above mentioned generalities, the effects of various treatments on other and more specific populations are mentioned below.

Figure 12.





Area A: All modes can be mixed. The only reason to consider bicycle tracks or bicycle lanes is for the sake of continuity of design on connecting bicycle routes.



Area B: In general, a profile without segregation is acceptable, but depending on circumstances bicycle tracks or bicycle lanes can be desirable.

Area C: Some form of separation is needed, but visual separation (bicycle lanes) can be acceptable as well.

Area D: Bicycle tracks are desirable, but as densities are low, a mixed profile is acceptable. However, bicycle lanes are not advisable.

Area E: Speed and/or density of traffic flow make it an absolute necessity to segregate bicycles and motor traffic. Separate bicycle tracks are the only option.

Note: above figure and text modified from http://strans.org/graph.html

Small distances, big hurdles

The market for NMT is strongest where distances are relatively short; this applies more to walking than cycling but still for cycling nonetheless. The central question is what distance defines a short distance and who defines it—a matter obviously related to the population travelling and the purpose. It is widely acknowledged that 70 percent of all trips in the Netherlands, for example, are less than 7.5 kilometers and that half of these trips (35 percent) are cycling (Ministerie van Verkeer en Waterstaat 2007). As expected, the percentage of cycling trips increases with shorter distances (44 percent of all trips in the Netherlands are less than 2.5 kilometers and, reportedly, 37 percent of them are cycling (Pucher and Buehler 2008, Figure 4)). Such startling statistics draw sharp focus to the potential of short trips.

According to the recent travel survey for the Melbourne Metropolitan Area, 40 percent of all trips are less than 2 kilometers—a surprisingly similar statistic to the Netherlands (less than 27 percent of trips in the U.S. are less than 2.5 kilometers (Pucher and Buehler 2008)). However, the mode share for cycling for these 40 percent of trips in Melbourne is nowhere near the 44 percent in the Netherlands.

This suggests that other impediments, are getting in the way—possibly related to culture, parking, lack of equipment (to carry goods), etc.—impediments which, if overcome, could go a long way towards increasing the mode split for cycling. Unfortunately, there are big hurdles to overcome and additional research could shed useful light on such matters (see section below).

The network is king

Given existing land use and transportation patterns in most communities, it is a lot to expect a comprehensive and seamless pedestrian and/or cycling network. It is also unrealistic to expect a city to realize such in short order time (e.g., a few years). This realization requires communities to creatively conceive of prioritized routes for frequented origins and destinations and to better improve conditions for existing routes with modest resources.

Doing so requires one to consider the larger network of bicycle facilities, map common origins and destinations, available routes, and to seize opportunities to amplify or improve the existing network. An overall network, after all, is what many users cherish (Lawlow *et al.* 2003), not just spot improvements here or there. Automobile transportation networks typically consist of neighbourhood streets, collectors, arterials, and freeways. A similar analogue could be considered for cycling routes, though not necessarily on the same routes as automobiles.

For example, in Boulder, Colorado, largely considered a leading city for bicycle transportation, the Bicycle System Plan identifies a network of primary and secondary corridors. Primary corridors (routes clearly demarcated for high levels of cycling) are spaced roughly one per 1.5 kilometers, with higher density and trafficked areas having less spacing between corridors. Secondary corridors are equally identified routes and generally rely on residential streets to further amplify the primary routes and to serve finer levels of geography.

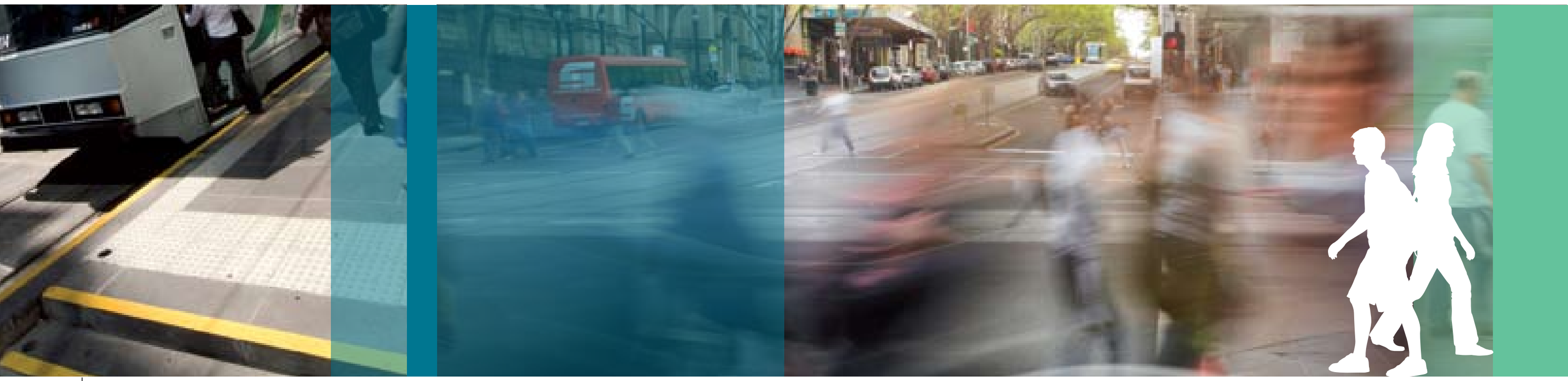
Figure 13: Confusion between trams, cyclists, and pedestrians along one of the existing primary bicycle corridors in downtown Melbourne, Swanston Street.

In other words, primary bicycle routes need not be facilities clearly separated from all other modes of travel, or facilities that require exorbitant resources. They merely require clearly identified and targeted routes with attention devoted to avoiding high levels of competition with other modes, particularly autos. In less travelled routes, multiple types of facilities could combine to provide users with strong wayfinding that is welcome and safe.

Furthermore, planned network and corridor designations are used to prioritize enhancements and the maintenance of existing facilities. They are used to identify target opportunities for completion as redevelopment opportunities arise. A central philosophy of a bicycle network plan is that the sum is more valuable than the parts. Rather than investing in spot improvements, a network philosophy stresses that improvements should be targeted, prioritized, and integrated within the larger system.

Redundancy of facilities is OK

There is often considerable concern expressed when SBFs—especially facilities clearly separated from auto traffic—are planned for corridors parallel to popular street bicycle routes. Such concerns are understandable



because efficiency is paramount and redundancy is often seen as a threat to such. In many instances, however, it is important to recognize that different types of facilities serve different users and that one size bicycle facility does not fit all. SBFs are particularly appealing for Class B and/or C users (more inexperienced); Class A users often prefer to be on the road amidst traffic because of higher travel speeds. In the right contexts, redundancy is all right and should not necessarily be avoided.

Intersections, crossings, and 'pinch points' are key

The decision to cycle is complex and multi-faceted. Sometimes a single element along the trip—a dangerous intersection, a troublesome bridge, a hairy road crossing—may be the single factor preventing people from cycling along a route. The merits of select intersection treatments were addressed above. However, the literature is non-existent in addressing crossing treatments in the form of under/overpasses. While these facilities are always more costly than at-grade crossings, they often go a long way towards accommodating timid cyclists and well-designed facilities with good sight lines should be strongly pursued, whenever possible, in discreet and strategic locations.

Figure 14: Examples of underpasses and overpasses

EXAMPLES OF UNDERPASSES AND OVERPASSES WITH PROBLEMS


Underpass without clear sight lines; Cumbernauld, Scotland.


Bicycle and pedestrian bridge with adequate but uninspired design and curvature that limits sight lines; Minneapolis, (U.S.).

BETTER EXAMPLES OF UNDERPASSES AND OVERPASSES


Underpass that is only partially below grade below raised roadway; Vallingby, Sweden. Sight lines are adequate.


Paired bicycle and pedestrian bridges; Amsterdam, Netherlands. Sight lines are good.


Bicycle (and pedestrian) underpass with clear sight lines; Canberra, Australia.


Pedestrian overpass; Millennium Park, Chicago (U.S.). Note, the metal railings do cut off views so the park is fairly heavily staffed with security.

Crossings and intersections may also be important for pedestrians—particularly when children or seniors need to cross busy streets or any pedestrian needs to wait a long time for a crossing signal. While there is little research on the effects of such crossings on overall levels of walking, it is logical that very slow or dangerous crossings would be a deterrent. The literature addressing crime prevention through environmental design has long been critical of underpasses as representing entrapment points, and this is true in many cases. However, if at-grade crossings are impossible or cost prohibitive, European experience demonstrates that such underpasses can be well designed with good sight lines although it is recognized that this comes at some expense.

AVENUES FOR VALUABLE FURTHER RESEARCH

Safety and measures of exposure

Discussions of NMT and safety usually focus on the number of crashes independent of amount of NMT travel crossing the area. This can sometimes lead to errant diagnoses because routes generally considered safe attract higher rates of use and thus more accidents. Thus, any discussions and research examining the safety of NMT needs to control for measures of exposure—that is, how much NMT there is in the area.

Detailed barriers for shorter trips

A reported 40 percent of all trips in Melbourne are less than 2 kilometers—a statistic relatively similar to the Netherlands. Yet Melbourne does not reach close to the 35 percent mode split for cycling in the Netherlands. This suggests a strong need to better understand the myriad reasons why residents choose not to cycle for these short trips. Is it culture, pricing, the lack of facilities or the inability to carry goods? In reality, it is probably a combination of each, but more in depth survey research is necessary to understand the detailed role of hypothesized impediments for these shorter trips.

TravelSmart and long-term follow up

As mentioned, initiatives such as TravelSmart and other education programs hold potential for shifting attitudes and use of NMT. A major shortcoming in understanding the strength of such programs is that there is a dearth of analysis that assesses the merits of these programs over longer term horizons (e.g., more than a few months or a year after the conclusion of the program).

Detailed accounting for NMT

In almost all dimensions, there is a dearth of reliable data about various dimensions of NMT (and accompanying urban form and network data). Data collection efforts, and subsequent analysis, need to be deliberate, focused, and aimed to address relatively specific questions. Notable areas of improvement include: measurement of short trips, attitudes/impediments toward short trips, purposes for all trips, the linking with other modes, etc.

Using walking/cycling to increase the transit-shed

Bicycling and walking are most appropriate for relatively shorter trips. But one should not dismiss how the shorter trips enabled by NMT can directly advance longer trips enabled by transit. Considerably more research is needed to build on the existing knowledge base to understand the conditions under which the transit-shed can be significantly broadened to include longer NMT trips. Some research has been completed looking at various dimensions of this puzzle (see for example, Martens 2004; 2007; Besser and Dannenberg 2005; Rietveld 2000b), but it is all very case dependent. More analysis is required to learn, for example: the distances residents are willing to travel to access multimodal trips, the convenience/impediments involved in bicycle on transit, how NMT distances differ for different ends of transit trips, bicycle parking requirements at transit stops, and the role of NMT signage outside of transit stops.

Substituting cycling for walking trips

Much research assumes that cycling trips will replace motorized modes. However, due to the significant effect of preferences and lifestyles of individuals, there is increasing evidence to suggest that pedestrians are most likely to be attracted to cycling. More systematic research is needed to assess whether NMT as a whole increases when cycling increases.

No "silver bullet" but how much of each type of program?

The strongest message contained in this report is that combined approaches are most successful to promote NMT. Available research, however, has underperformed in allowing users to learn more about the relative impact of each approach, that is, how important are education, infrastructure, community design, signage or other interventions. Teasing out the relative contributions of each is difficult. However, further research pursued within the rubric of combined measures will help planners better understand the relative impact of each and discern where to devote additional resources, all matters considered

Figure 15: Bicycle facility along Beach Road (south of Melbourne) with the skyline in the background.