Promoting Walking and Bicycling: Assessing the Evidence to Assist Planners

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How can people be encouraged to walk or cycle more? This article draws on the results of over 300 well-designed empirical studies to provide guidance on how specific strategies can influence walking or cycling for travel: community design, infrastructure availability, infrastructure quality, programming, pricing, and combined strategies. Urban environments with high levels of walking and cycling for travel typically represent a combination of many factors that help promote these modes. The most compelling argument, particularly for cycling, is that only via an integrated range of built environmental features (including infrastructure and facility improvements), pricing policies, or education programmes will substantive changes result. This is what has been occurring in The Netherlands, Denmark, and parts of Germany for decades. By linking research to practical advice, the article fills a gap between (a) the many excellent literature reviews pointing to where further research is needed and (b) useful practice-oriented guidelines based on experience.

If one were to pick up any community's recent transportation plan or pay attention to the goals and objectives of their transportation initiatives you would be likely to detect a common thread: an aim to increase levels of walking or cycling. Many benefits are claimed for places where such modes are frequently used: reduced traffic congestion, lower use of resources, fewer greenhouse gas emissions, reintegration of physical activity into daily routines, and improved quality of life. The outstanding question in all of this, however, remains: what strategies are more successful than others in spurring levels of walking and/or cycling? How is this to be done?

Answering these questions fully is difficult. However, thanks in part to an active and growing literature on the subject, planners can find increasing guidance. To some extent any answer to these questions of 'what works and what does not' is 'it depends'. For example, it depends if one is referring to walking or cycling trips for the utilitarian purpose of getting somewhere (what we refer to as walking or cycling for transportation or travel purposes) versus engaging in walking or cycling for recreation. The two have different motivations and need different kinds of support. Some strategies can help promote these non-motorized transportation modes but at substantial cost – are they worth it? It depends.

This article draws on a comprehensive summary of the recent literature on walking and cycling to understand better why people fail to walk or cycle more and, specifically, what planners can do to encourage these non-motorized modes. Through linking research to practical advice the article fills a gap between (*a*) the many excellent literature reviews that point to where further research is needed and (*b*) useful practice-oriented

guidelines based on experience. It focuses on a broad spectrum of 'levers' – both hard (physical) and soft (non-physical). It further breaks this spectrum down to six categories:

- Community or urban design, that is, the overall layout of places.
- Infrastructure availability relating to whether facilities such as cycle ways and footpaths are provided.
- Infrastructure quality which goes a step further to examine whether better designed, more attractive, and often more expensive infrastructure males a difference.
- Programming, including such activities as education and marketing.
- Pricing and convenience, a category related to the relative time and money costs of motorized and non-motorized modes.
- Combined strategies where multiple approaches – such as pricing, education, and infrastructure provision – reinforce each other to give clear signals about the potential for non-motorized transportation.

To assess reliably the state of the research across these six categories, as we describe in more detail below, we conducted a review over 300 studies addressing aspects of walking and cycling and extracted policy and planning-relevant conclusions based on the preponderance of evidence (Krizek *et al*., 2009*a*).

The review found that:[1]

- The availability of infrastructure is very important for cycling. This includes, to some extent, its quality. It is less important for adult pedestrians.
- For adults who walk for transportation, overall community design matters more than infrastructure.
- Soft measures – from educational campaigns to pricing policies – potentially have a lot to offer. In terms of educational and marketing campaigns, however, few studies have followed participants long enough to see if they change behaviour over time.
- High-income countries where people cycle a lot use every possible strategy to support cycling – education, pricing, infrastructure, and community design. The Netherlands, Denmark, and Germany are the poster children for such an approach (Pucher and Buehler, 2008). A corollary is that small, isolated interventions typically have small and isolated effects.
- Recreational walking and cycling (for exercise, fun, or for the sake of travel) overlap in practice with walking and cycling for transportation (to get somewhere such as work, shopping, or services). This often muddies analyses. However, often recreational and travel activities have different infrastructure and community design needs; leisure walking in particular tends to happen in different places to travel walking. The focus in this article is on utilitarian activity.
- The review confirms a substantial literature that argues for addressing walking and cycling separately in policy and planning (Oregon Department of Transportation, 1995; Forester, 1994; Zegeer, 1998; Forsyth *et al*., 2009*a*).

General findings are summarized in table 1 where high, medium, and low indicate the authors' assessment – based on the literature and where there is enough evidence to draw a conclusion – of how important a strategy is for increasing walking and cycling. Areas where there are not enough evaluations are also indicated.

This article examines common misunderstandings about walking and cycling such as a tendency to assume that interventions will have larger effects than the literature confirms. One of its main contributions is to assess the state, clarity, or consensus of existing knowledge and point to specific areas

Table 1. Summary matrix showing the efficacy of different categories of policy levels. (Adapted from Krizek *et al*., 2009*a*)

Strategy	*Increasing Walking*	*Increasing Cycling*
Community Design	High	Medium
Infrastructure Availability	Medium for adults; High for children	High
Infrastructure of High Quality (e.g., wide, tree-lined footpaths throughout)	Low	Medium
Programs (campaigns, education, and marketing)	Insufficient robust evaluations	Insufficient robust evaluations
Pricing and Convenience	Medium	Low
Combined Strategies	High	High

that are 'known' versus those that are 'grey' – thereby helping to direct future inquiries. It outlines the low hanging fruit in terms of interventions, policies and programmes that seem promising but have not been evaluated sufficiently, and where research findings contradict common assumptions. A main conclusion from our systematic review underscores the importance of employing multiple strategies.

Existing Knowledge and Our Methods

The existing literature on walking and cycling is quickly gaining ground in terms of quality and breadth. Work stems from several different interests embodied in different professions – for example, increasing liveability (from those in urban design), promoting efficiency (traffic engineering), preserving the environment (urban planning), or encouraging physical activity (public health) (Forsyth *et al*., 2009*a*).

The literature examining relationships between *various dimensions of travel behavior* (including walking and cycling) *and land-use characteristics* is extensive. Many literature reviews have been published on this broad area (Badoe and Miller, 2000; Crane, 2000; Ewing and Cervero, 2001; Van Wee, 2002) and more appear each year (e.g., Ewing and Cervero, 2010) focusing on different dimensions, contexts, or meta-analyses.

Walking and/or cycling are the primary focus of still more such reviews (Saelens *et al*., 2003; Owen *et al*., 2004; Ogilvie *et al*., 2004, 2007; Saelens and Handy, 2008; Krizek *et al*., 2009*a*; Giles-Corti *et al*., 2009; Pucher *et al*., 2008, 2010; Cao *et al*., 2009). Others, generally from public health, deal with walking as part of a broader concern with physical activity (Humpel *et al*., 2002; Trost *et al*., 2002; Handy, 2004; Davison and Lawson, 2006; Heath *et al*., 2006; Ferreira *et al*., 2007; Gebel *et al*., 2007; Wendel-Vos *et al*., 2007). Depending on the orientation of the review, however, the research findings that are presented may be easier or more difficult to apply to public policy decision-making relating to the built environment. The notion that the built environment affects travel behavior is now widely accepted, but the magnitude and character of this relationship is still a matter of contention (Ewing *et al*., 2008; Transportation Research Board, 2009).

Our approach for this investigation was straightforward. We sought to review the knowledge base consisting of international, English-language studies that could help policy-makers understand barriers to walking and cycling for daily trip purposes as well as what could be done to overcome such

barriers (Krizek *et al*., 2009*a*). We located over 500 reports, articles, and books addressing research on walking and bicycling. We then applied three filters.

- The first was to review studies, which we deemed to have sufficiently robust methods; empirical studies that had undergone peer review were preferred.
- The second was to focus on studies evaluating, rather than describing, interventions.
- Third, we sought studies that squarely addressed some notion of walking and cycling primarily (though certainly not exclusively) as opposed to studies addressing more general notions of travel. However some studies looking at walking and cycling amidst other modes such as transit or automobile were important.

The outcome was a thorough review of 300 studies with publication dates up to early 2008 – a set of literature that has been updated for this article with additional and recent reviews or studies. Of course, some areas where such evaluation literature was lacking are underrepresented, an example is long-term assessments of educational programs to promote walking and cycling (Krizek *et al*., 2009*a*; Baum *et al*., 2009).[2] For each study, we inventoried seven characteristics for the research effort:

- Mode: whether the focus was cycling, walking or both.
- Main focus of the article in terms of interventions, strategies, environmental features, or outcomes: e.g., community design, infrastructure, mode choice, modelling, programming. This is an eclectic category reflecting the diverse literature.
- Literature type: including peer reviewed, conference paper, report by agency, book, or other.
- Research approach: including evaluation of an intervention, cross-sectional survey (single time period), etc.
- Place or density: whether in a large core city, suburban area, ex-urban context (that is, within commuting distance of suburban areas), rural location, etc.
- Sample characteristics including: who, where, when, how collected, and how many respondents.
- Outcome variables, such as type of walking and/or cycling examined e.g. utilitarian/travel, commuting only, recreational, total activity, etc.
- Basic findings or conclusions about the relationship between interventions and walking and cycling (Krizek *et al*., 2009*a*).

This approach meant we carefully assessed each study's conclusions in relation to the data and methods used. This article draws on this substantial review, updated with more recent literature,[3] to provide recommendations for those wishing to promote walking and cycling. The studies we cite directly are not intended to be exhaustive but rather representative of the larger review. In a number of areas results from different studies are contradictory and there we have focused on the preponderance of evidence, where multiple studies agree. We conclude each section with summary recommendations for policy and planning; and provide more extensive recommendations in the conclusion.

Hard Measures: Community and Infrastructure Design

Community Design Overview

Community design, or general neighbourhood and town layout, has four overall (and often co-mingled) dimensions relevant for non-motorized transportation: land use, urban design characteristics, street pattern,

and development intensity. This is an area of great interest in urban planning, demonstrated by substantial research activity. Most of this literature focuses on how community design results in variations in automobile use. However, while some propose that decreasing car use will increase walking and cycling the research is not clear on this matter (Handy and Clifton, 2001). Walking and cycling may complement not substitute for auto use. Transit rather than walking and cycling may replace driving. In addition many studies combine walking and cycling, making it difficult to determine the effects by mode (Krizek *et al*., 2009*a).*

Research specifically focused on walking, cycling, and community design – from transportation and increasingly from the health field – has tended to focus on how specific dimensions of community design affect walking and/or cycling. For example, one body of work examines the effects on walking of the distribution of destinations or densities of population and housing. Many of the health studies look at physical activity in general or walking and cycling in total, not just for transportation. A number assess whether other factors – such as socio-economic status or self-selection – underlie apparent associations between community design and active travel (i.e. walking and cycling).

Walking Findings. For adults, numerous studies demonstrate that walking for utilitarian purposes is correlated with a mix of community design features: having access to many destinations and higher population densities (though density is often a proxy for other variables). Some but not all studies find effects from street connectivity. However, different studies emphasize different community design features.

For example, Cervero and Duncan (2003) analyzed two-day travel diaries and built environmental features using GIS to uncover that only land-use mix was a statistically significant predictor of walking trips. Lee and Moudon (2006) asked 438 respondents in Seattle about walking '(a) to work, (b) to school, (c) to grocery stores, (d) to other retail or service facilities, and (e) for recreation or exercise'. They proposed several variables that facilitate walking. Travel or transport walking varied with distances to office and mixed-use centres, restaurants, banks, post offices, and grocery stores; along with slope, parcel density, and area density (*Ibid*.). Sidewalks, dealt with in the next section of this paper, were not significant. Forsyth *et al*. (2007, 2008, 2009*b*) used surveys and 7-day travel diaries from 716 people and found associations between travel walking and higher densities, connected street patterns, sidewalks, social land uses (such as libraries, day care, clinics, theatres, sports areas, recreational facilities, and places of worship), and audit-measured litter and graffiti. Studying subgroups of the population – defined by a range of issues from obesity level to presence of children and race – they found most subgroups walked more for transport in higher density areas, including such locations in both the core city and in suburbs.

Built environments with destinations closer together are definitely correlated to higher rates of walking for transportation. A relatively outstanding question, however, is how close is close enough. Some people routinely walk much more than the quarter mile (400 metres) proposed in many professional circles as a reasonable distance. Using a one-day travel from 26,000 households, Agrawal and Schimek (2007) found that while 35 per cent of respondents failed to report walking, 8.7 per cent of trips were walk-only and most of the 2 per cent of transit trips started with a walk trip. The median walk trip was 0.25 miles or 402 metres, however such trips averaged 0.62 miles (998 metres) with 23 per cent over one mile or 1,609 metres. Approximately one-fifth of trips were to or for recreation, with more highly educated people doing more such trips (*Ibid*.). Agrawal and Schimek found utilitarian walking was greatest for households living

at high population densities measured at the census block group level (25,000 people per square mile measured at the census block group level, or 97/ha), no car ownership, the lowest incomes, and higher educational levels.

Others have found similar distances including: average walking distances of more than 600 metres to transit in Singapore (Olszewski and Wibowo, 2005); and over 40 per cent of transit-riders in Toronto residing over 300 metres as the crow flies distance from transit (typically substantially more on the street network) (Alshalalfah and Shalaby, 2007). What remains unclear is if the current situation represents all those willing to walk further or if there are additional people prepared to go further with appropriate carrots and sticks in place (Krizek *et al*., 2009*a*).

The literature on children's walking and community design is distinct (Whitzman *et al*., this issue, specifically address mobility of children and relevant literature). Their level of personal choice varies by age; for younger children parental perceptions filter effects of community design. A great deal of the literature on walking (and cycling) is from the perspective of health where the focus is less on trips and more on time spent being physically active. However, some dimensions do seem important. Work on children has found that both actual and perceived distance and barriers, like busy streets, matter in the walk to school (Ewing *et al*., 2004; Timperio *et al*., 2006; Black *et al*., 2001; Timperio *et al*., 2004; CDC, 2005). Giles-Corti *et al*., (2009) reviewed the literature on environments, out of school time physical activity, and walking and found having attractive destinations was important for older children who had greater independence from their parents. However they noted many contradictory findings related to age, ethnicity, and socioeconomic status and called for better research (see also Saelens and Handy, 2008). As we describe below, infrastructure (including safety-related issues) and education have been stronger areas of focus for studies and intervention related to children's walking than has community design.

Overall, density is a strong predictor of walking in many but not all studies, largely because it means destinations are closer to one another. Destinations or mixed land uses are often found to be associated with walking for transportation, though the specific destinations differ by study. There are mixed findings about whether parks and recreation facilities promote travel walking (see also Saelens and Handy, 2008). Street patterns matter in some studies, but in others are not significant. This may reflect measurement problems – for example few databases of street patterns also include a complete set of pedestrian routes – but it may also reflect the complexity of this topic (Saelens and Handy, 2008; Krizek *et al*., 2009*a*).

Cycling Findings. Distances between origins and destinations are key factors in the decision to cycle, providing an obvious link to matters of community design. Bicyclists, of course, can move faster than pedestrians and so are typically willing to go further. However, there are limits. Similar to inquiries for walking, it is relatively unclear as to the distance 'sweet spot' for cycling in terms of trip length and the degree to which they can be switched from auto. In Europe, for example, average trip distances for all modes are shorter than in the US, largely attributed to higher development densities. Pucher and Buehler (2008) report that 44 per cent of trips in The Netherlands, 37 per cent in Denmark, and 41 per cent in Germany are shorter than 2.5 kilometres. These values are in stark contrast to 27 per cent in which is present in the US (Pucher and Buehler, 2008, and this issue).

Furthermore, there is evidence to suggest cyclists travel different distances for different kinds of trip purposes or destinations. For example, cycling trips for transportation are considerably shorter than for recreation (Xing *et al*., 2010). A study in the Twin Cities area of Minneapolis/Saint Paul, Minnesota, found

recreation, entertainment, and fitness trips to be longest (at around 30 to 40 km); work next (20 km); and shopping, and rail access trips typically being under 10 km (Iacono *et al*., 2007, p. 13). Looking at data from The Netherlands, Germany, and the UK, Martens (2004, p. 281) found typical cycle trip distances to access transit services ranged 2 to 5 km, but there were longer distances to faster modes (e.g., commuter train). So, while cyclists' trips are less sensitive to distances than pedestrians (mentioned above), it is still an issue.

These findings for walking and cycling beg one to consider a largely unresolved issue in the literature: self-selection. The nature of walking and cycling travel might have less to do with community design than other factors such as personal preferences. In what is probably the most comprehensive and recent review on the subject to date, Cao *et al*., (2009) examined thirty-eight studies analyzing features of community design, and the degree to which higher levels of walking (and sometimes cycling) were reflected in self-selection. The review found statistically significant built environment effects. It was difficult, however, to conclude the relative magnitude of the built environment relative to other factors, as few studies reported such (*Ibid*.).The prevailing consensus to date is that both factors – the built environment and issues of self-selection – lead to heightened levels of walking and cycling.

Infrastructure

Commonsense proposals for increasing walking and cycling often focus on building facilities specifically oriented for their use. Relative to altering the street pattern or overall density such changes may be inexpensive. Walking and/or cycling facilities can also be integrated with a wide variety of existing roads and streets (apart from freeways).

Walking Findings. Walking infrastructure varies by population: able-bodied adults, children, and people with substantial mobility impairments.

For able-bodied adults infrastructure has unclear utility. While many policy proposals assume sidewalks or footpaths are a prerequisite for walking, research is mixed. Some find sidewalks to be significantly associated with travel walking (Forsyth *et al*., 2008); others do not (Lee and Moudon, 2006, p. S77). Hoehner *et al*. (2005, p. 105) adjusted survey results for age, sex, and education, and found that people walked *less* for transportation in areas with more level sidewalks (as measured). In contrast they walked *more* in areas with '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 neighborhood'. Other studies have found some associations with pedestrian infrastructure but there are different associations in each study. As Saelens and Handy (2008, p. S562) state in a review of studies published in 2005 and part of 2006: 'there was little or no evidence in these studies for relations between transportation walking and pedestrian infrastructure conditions, traffic-related issues, aesthetics, or accessibility of physical activity facilities'. This probably indicates the more substantial importance of community design, social, and economic factors in transportation walking (Krizek *et al*., 2009*a*) (see figure 1).

The perceived environment is also important but not clearly related to providing infrastructure. Studies comparing perceived and measured environments find very modest associations (McGinn *et al*., 2007; Jilcott *et al*., 2007, for more discussion of this subject see Timms and Tight, this issue).

Children are a different group; they, and in particular their parents, may be less confident about walking without sidewalks, footpaths, street crossings, and other similar infrastructure. Walking to school has been found to increase where there are sidewalks along main roads (Ewing *et al*., 2004); crossings, an

A mixed-use environment with relatively high residential densities is typical of places with substantial amounts of travel walking. However, this environment also has policy and social supports for walking: it is near a university that supplies little parking and incomes are relatively low (Minneapolis, MN).

The pedestrian infrastructure in this image is less well supplied and maintained than the image to the left. However, the underlying densities and mix of uses support walking. The area's population is also relatively low income, so likely to walk for economic reasons St. Paul, MN).

Recreational walking may occur in different kinds of environments compared with travel walking (Columbus, IN).

Figure 1. Walking environments. (*Photos*: Ann Forsyth)

absence of busy roads (Giles-Corti *et al*., 2009); and well-publicized sidewalk gap-closure projects that both improve infrastructure and make people aware of the improvements (Boarnet *et al*., 2005*a*, 2005*b*). However results vary by age, sex, and so on (Davison and Lawson, 2006). Dumbaugh and Frank (2007) reviewed the literature on safety and found pedestrian crashes decreased where there were sidewalks and raised medians (though not pedestrian crossings). However, in the area of children's mobility perceptions are also key (Giles-Corti *et al*., 2009). Education of parents, children, and motorists may help promote children's walking. Interventions such as traffic calming and high visibility safety improvements (lighting, crossings, paths) may also increase perceived safety (see figure 2).

People with substantial mobility impairments are likely to need better – wider, smoother, and more brightly lit – infrastructure because they may be using wheeled mobility aids such as walkers

One strategy for providing more safety for children is to place them on separated paths in the mode of Radburn planning. This example involves a separated path for cyclists and pedestrians. The photograph shows a street underpass below a raised roadway in Vallingby, Sweden. Sight lines along the path are adequate in the daytime.

An alternative is to provide footpaths or sidewalks beside the street. This is a particularly generous multipurpose sidewalk in Izumi Park Town in Japan. The design allows plenty space for different users and clearly separates pedestrians and cyclists from motorized traffic.

Figure 2. Paths oriented toward safety for children. (*Photos*: Ann Forsyth)

and wheelchairs. There is not an extensive literature on this topic, however.

In general, infrastructure investments may be useful in changing the perceptions of walkability among children and their parents. For adults, however, the relationship between infrastructure and increased travel walking is not strong. Providing a level of infrastructure that will allow those with mobility impairments to get around will be more than adequate for the rest of the population. Certainly more elaborate infrastructure may be pleasant and add to quality of life. It is worth providing for those reasons. But evidence for it increasing walking among able-bodied adults is weak.

Cycling Findings. For cycling the story is different, and cycling infrastructure is important. The literature consistently suggests that the dearth of cycling infrastructure is a major detriment in terms of spurring cycling. The unresolved matter relates to understanding which type of cycling infrastructure is best and for whom? For example, more bicycling facilities – on- and off-street – appear to provide great advantages (Dill, 2009). But once analysis drills down to specifics it can be difficult to understand the effects of different types of cycling infrastructure. This is largely because of: (1) the lack of reliable data on the matter; (2) the wide range of different types of treatments so that it is difficult to compare evaluations; (3) the role that different kinds of intersections play; and (4) the relatively wide range of skills levels of users (compared to pedestrians).

From this standpoint, a large, looming, and relatively unresolved issue is the question of separated bicycle facilities versus cycling with other traffic. Researchers have investigated whether they are useful and if so, which types are best. Separated Bicycle Facilities (SBFs) refer to a range of facilities that are within the right-of-way, separated from motor vehicles, and aim to reduce interactions between cyclists, pedestrians, and motor vehicles. Separation is achieved through a variety of means including bollards, medians, raised paving with kerbs, and vehicle parking, though it can also take the form of a completely separate path, several metres from the road (Krizek *et al*., 2009*a*). The Netherlands and Denmark are well known for their extensive use of such facilities with practitioners in other countries exploring the degree to which they can replicate their success.

There are two main reasons why SBFs are typically proposed: improving safety and increasing use. These are described below. In general many argue that *the costs of SBFs outweigh the benefits*, though this could be because approaches for reliably quantifying benefits are difficult to address or come by (Krizek, 2006; Krizek *et al*., 2007; see also Macmillen *et al*., this issue). While it seems common sense that SBFs improve cyclist safety, in the field of transportation this is a controversial claim (Forester, 2001; Pucher, 2001) (see figure 3). Several key arguments help frame the debate:

- The main argument against safety claims for SBFs is that, on balance, *actual crash data fail to support claims that SBFs are safer.* This is because most conflicts between motor vehicles and bicycles occur at intersections or where turning movements occur, not where the two modes are travelling in the same direction. Separating cyclists and others, in this view, only serves to make intersections more complicated, leading to additional conflicts and accidents (Summala *et al*., 1996; Räsänen and Summala, 1998; Pedler and Davies, 2000; Aultman-Hall, 2000; Wachtel and Lewiston, 1994).

- Other work relating to on-street bicycle lanes has, however, noted less vehicular encroachment, more distance between cars and cyclists, and cyclists riding further from the road edge with such facilities compared with roads without such lanes or with only

(*a*) (*b*) (*c*)

Separated Bicycle Facilities (SBF's) come in all shapes and sizes: (*a*) contra flow lane in downtown Boulder, CO; (*b*) specialized treatment at an intersection near Swiss Cottage, London; and (*c*) a downtown corridor in Montreal. While increased safety is a primary justification for these treatments, the bulk of the available research is unable to confirm reliably this. Nevertheless, they appear to increase perceived safety among select groups such as the elderly, children, and inexperienced cyclists.

Figure 3. Separated bicycle facilities. (*Photos*: Kevin J. Krizek)

wide kerb lanes (Harkey and Stewart, 1997; Hunter *et al*., 1999, 2005; Hallett *et al*., 2006). Dill (2009, p. S101) used GPS to collect trip route data from 166 regular cyclists over seven days (1,800 trips) and found that almost half the miles of bicycle travel 'occurred on roads with bicycle lanes, [separated] paths, or bicycle boulevards', facilities that made up only '8% of the available network'. A follow-up survey indicated that the top reasons for choosing paths were directness and avoiding traffic.

◆ In spite of mixed evidence, there is a perception that SBFs increase safety. This may lead to more cycling. Places with more such activities have lower collision rates (Jacobsen, 2003). However, studies have mixed findings with respect to bicycle lanes and increased cycling; some find a positive association (Dill and Carr, 2003), some find none (Moudon *et al*., 2005), and some find effects only at close distances (Krizek and Johnson, 2006). Cycling infrastructure might also attract cyclists to particular communities by creating the perception that they are bicycle friendly (Xing *et al*., 2010).

Several confounding or unresolved issues present a mixed picture with respect to cycling and SBFs; these include but are not limited to lack of: (*a*) systematic inquiry accounting for cyclists with different experience levels and personal characteristics; (*b*) detailed accounts of safety records relative to SBFs (to better control for issues of exposure); and (*c*) studies that distinguish adequately between different kinds of SBFs. The literature appears to agree on two dimensions however: (1) that intersections are particularly problematic; and (2) places with higher rates of cycling have superior safety records (per capita or per users) (Jacobsen, 2003; Ewing and Dumbaugh, 2009; Marshall and Garrick, 2010).

Soft Measures: Pricing, Programming, and Education

Pricing: Driving and Parking

Walking and bicycling compete with other modes in terms of travel choices and thus relative cost is an important consideration. Relative cost is a function of both policies and markets. For example, many argue that automobile users pay less than the social and ecological cost of their mobility choice with their travel mode subsidized by road financing mechanisms, low-cost parking, and low fuel taxes. In the US, Shoup (2005)

has estimated that 99 per cent of car trips begin and end with free parking; differences in the cost of driving explain much of the difference in automobile use between the US and Europe (Pucher, 1988). Many studies find low-income people walk more for transportation (van Lenthe *et al*., 2005, p. 763; Agrawal and Schimek, 2007). Furthermore, a study of almost 900 people in Minnesota and Maryland found that, after controlling for socioeconomic factors, perceived parking was the strongest association between a variety of perceived and measured environmental variables and weekly travel walking and total walking (Rodriguez *et al*., 2007).

At first blush, it may appear a bit off target to focus on larger factors related to pricing and parking. Any effort, however, to understand better how to increase levels of walking and cycling is best positioned against the wider context. While only a few studies we reviewed specifically tackled this thorny issue, in other studies there were countless implicit references to the larger transportation policy and planning context.

Programmes and Education or Social Marketing Efforts

While environmental and policy changes provide important options for helping change people's behaviour, education and social marketing efforts also have a number of attractions. Such efforts include walking clubs, school- or work-based programmes, and personalized travel planning. Many of these programmes are focused on voluntary Travel Behaviour Change (TBC) through providing individuals and households with more information about travel, mobility and communications options.

Few such programmes have been robustly evaluated for their potential specifically to increase walking and cycling; rather, the focus has been on decreasing automobile use or increasing transit. Furthermore, follow up periods are typically short, measuring changes at the end of an intervention or up to a year or so after. Some results have been reported, however. A four-week long elementary school curriculum in New Zealand found the most sedentary children increased the number of steps they took, though there was no significant effect on the group as a whole. Studies of adults sometimes find modest but significant changes, particularly in motivated groups (e.g., Ball *et al*., 2005; Clarke *et al*., 2007; Dinger *et al*., 2005; Goulias *et al*., 2002; Mutrie *et al*., 2002; Reger *et al*., 2002; also Ogilvie *et al*., 2004), but others comparing controls or different types of intervention do not find differences or find quite minimal educational campaigns to be as effective as more elaborate interventions (Brownson *et al*., 2005; Chen *et al*., 1998; Williams *et al*., 2008). Other studies have found such programmes might promote cycling but at the expense of walking (Merom *et al*., 2003). Overall systematic reviews of such educational and marketing programmes conclude they show modest promise (Ogilvie *et al*., 2004; Williams *et al*., 2008; Taylor 2007).

Bicycle Loan Programmes

Finally, a compelling, though not necessarily original 'hybrid' combining both hard (the actual supply of bikes) and soft (publicity, marketing, metering their use) approach involves bicycle loan programmes (see figure 4). There has been much hype but scant evaluation to date. Existing evaluations are not strikingly positive in terms of increasing cycling for utilitarian purposes. Noland and Ishaque (2006) found a London programme was mainly used for leisure and recreation trips with few repeat users. Most evaluations focus on programme use rather than effects on cycling levels (Pucher *et al*., 2010, p. S114).

Conclusions: Making Sense of the Literature on Promoting Walking and Cycling

Many planners, policy-makers, politicians,

(*a*) (*b*) (*c*)

Bicycle loan programmes have been implemented in a number of cities worldwide, including: (a) Vienna, (b) Paris, and (c) Dublin. The available research on such programmes, however, has not kept up with their adoption, leading to a need for information about their efficacy and patterns of use.

Figure 4. Examples of bicycle loan programmes. (*Photos*: Kevin J. Krizek and Ross Corotis)

and activists suggest that promoting walking and cycling will better enable communities to address a number of concerns from public health to resource protection (Krizek *et al*., 2009*b*; Forsyth *et al*., 2009*a*). The mushrooming literature on walking and cycling signals this increasing interest. In this section we undertake three tasks:

- We first comment on common misunderstandings.
- We outline key findings from the literature on specific types of environments or users.
- We conclude by commenting on the state of this literature, broadly speaking, and proposing larger policy and planning implications.

Debunking Common Misunderstandings

Conclusion 1. Walking and cycling, while sharing a number of commonalities, are different enough activities to warrant separate consideration. Hard and soft interventions to promote one do not necessarily work to promote another. Some strategies (e.g., educational campaigns or decreasing average trip distances) jointly promote both. But other initiatives (e.g., specific infrastructure or other provisions) sufficiently differ between the modes and require specific analysis. Furthermore, while most of the general population walks, those who cycle comprise a considerably smaller population who also vary in their preferences in ways that deserve more assessment.

Conclusion 2. Walking and cycling are understudied and in the absence of information people often overestimate effects of proposed interventions. In particular people have a hard time assessing the relative importance underlying preferences and lifestyle choices compared with infrastructure. As a corollary, much practice and some research assumes that if people get out of cars they will start walking. This is not necessarily the case.

Specific Environments and Users

Conclusion 3. Some populations represent low hanging fruit in terms of responding to education or infrastructure interventions. These populations include:

(*a*) Those who have *recently moved* may be open to travel change, if they can be recruited (something which has proved difficult) (Dft, 2006; Ampt *et al*., 2006).

(*b*) Those with *low incomes* are sensitive to pricing strategies.

(*c*) People without *driver's licenses or with less confidence driving* (youth, seniors) may be open to walking and cycling more. However, these decisions are heavily related to personal factors; for example, seniors' confidence in their ability to walk (Naumann *et al*., 2009).

(*d*) *Young, old, and female cyclists* who typically are less confident about riding bicycles. They also may have slower reflexes, less experience, or more aversions to risk (Krizek *et al*., 2005). These groups might respond to cycling infrastructure interventions that help them perceive cycling as safer.

Conclusion 4. Some promising interventions that deserve attention have not been evaluated well enough to conclude that they really work.

(*e*) Education and social marketing may make a difference, particularly for those who are motivated. It may also be helpful in changing the perceived environment, which is important for a number of populations, for example children and their parents.

(*f*) *Bicycle loan programmes* may be attractive to certain groups, such as people in core cities, tourist destinations, or on university campuses. However, there is not enough research on how they work to make clear conclusions.

(*g*) *Increasing transit, or creating car-free zones*, may well increase walking but the amount of this effect is not clear.

Conclusion 5. Some interventions and rules of thumb that may seem obvious are not backed up by research evidence.

(*h*) *Distance* is important to pedestrians but many will walk further than the planning rule of thumb of 0.25 mile or 400 metres; while distance is still important for cyclists, it is difficult to arrive at an agreed-upon distance.

(*i*) Pedestrian *infrastructure* such as footpaths matter to some users but not others.

(*j*) The findings on *separated bicycle facilities* are mixed; empirically, they are not safer (rather on-street bicycle lanes and wide kerb lanes may be better), in part because intersections are one of the most problematic locations for cyclists and they make intersections more complex. How However, they are perceived as safer which might increase ridership. Higher levels of ridership do increase safety.

Larger Planning and Policy Implications

Conclusion 6. There is no single solution (silver bullet) when it comes to increasing walking and/or cycling however there are certain necessary (if insufficient) preconditions. For walking

The experience levels of different types of users, particularly cyclists, may warrant redundant treatments such as these parallel on and off road cycle lanes and paths (Tauranga, New Zealand).

Adequate infrastructure is key for cyclists, but educational or awareness campaigns can help as well (Welcome Bay, New Zealand).

Infrastructure treatments are often thought of as sidewalks or bicycle lanes, but other treatments such as prioritized signals have not had much study (Münster, Germany).

Figure 5. Examples of combined strategies for cycling. (*Photos*: Kevin J. Krizek)

such preconditions include neighbourhood and larger scales of design (such as density and accessible destinations); for cycling, adequate infrastructure. Other carrots – such as attractive aesthetics – have far less effect.

Conclusion 7. Combined strategies work to increase walking and cycling; i.e. it is very helpful to combine infrastructure, community design, pricing, and enforcement of traffic regulations. While it is hard to measure the relative effects, the importance of pricing of alternatives seems very important (e.g., parking, fuel taxation). An integrated package of many different, complementary interventions, including infrastructure provision and pro-bicycle programmes, supportive land-use planning, and restrictions on car use is what has been occurring in The Netherlands, Denmark, and parts of Germany for decades (Pucher and Buehler, 2008).

Conclusion 8. Better information about non-motorized travel, collected at small geographical scales, would help planning for these modes. Key areas where more research is needed include the travel patterns and needs of specific population groups such as older people, those with low incomes, and people who might fear victimization in public spaces. Such detailed evaluation is made particularly difficult, however, by the wide range of facilities for non-motorized transportation: footpaths, trails, parking lots, low volume roads, high volume roads (pedestrians crossing and cyclists moving along), parks, and so on (Heinen *et al*., 2010).

NOTES

1. This article draws on a literature review published as a government report. While the article follows a similar structure to the report, the focus is on making more general policy and planning recommendations.

2. This review and the inventory of all 300 key research papers are available as a government report (Krizek et al., 2009*a*). Available at http://www.transport.vic.gov.au/DOI/DOIElect.nsf/$UNIDS+for+Web+Display/70D43560D1141DDFCA2575E8000BA1EE/$FILE/WalkingCyclingLiteratureReview.pdf.

3. See also Pooley *et al*., this issue for additional review of studies on similar issues.

REFERENCES

Agrawal, A.W. and Schimek, P. (2007) Extent and correlates of walking in the USA. *Transportation Research D*, **12**(8), pp. 548–563.

Alshalalfah, B.W. and Shalaby, A.S. (2007) Case study: relationship of walk access distance to transit with service, travel, and personal characteristics. *Journal of Urban Planning and Development*, **133**(2), pp. 114–118.

Aultman-Hall, L. (2000) A summary of the safety related results of a Canadian bicycle commuter survey, in *Traffic Safety on Two Continents*: London: PTRC.

Ampt, E., Wundke, J. and Stopher, P. (2006) Households on the move: new approach to voluntary travel behavior change. *Transportation Research Record*, No. 1985, pp. 98-105.

Badoe, D. and Miller, E. (2000) Transportation–land-use interaction: empirical findings in North America, and their implications for modeling. *Transportation Research D*, **5**(4), pp. 235–263.

Ball, K., Salmon, J., Leslie, E., Owen, N. and King, A.C. (2005) Piloting the feasibility and effectiveness of print- and telephone-mediated interventions for promoting the adoption of physical activity in Australian adults. *Journal of Science & Medicine in Sport*, **8**(2), pp. 134–142.

Baum, L., K. Krizek, and A. Forsyth (2009) Appendix A, in Krizek, K., Forsyth, A. and Baum, L. (eds.) *Walking and Cycling International Literature Review*. Melbourne: Department of Transport.

Black, C., Collins, A. and Snell, M. (2001) Encouraging walking: the case of journey-to-school trips in compact urban areas. *Urban Studies*, **38**, pp. 1121–1141.

Boarnet, M., Anderson, C.L., Day, K., McMillan, T. and Alfonzo, M. (2005*a*) Evaluation of the California Safe Routes to School legislation: urban form changes and children's active transportation to school. *American Journal of Preventive Medicine*, **28**, pp. 134–140.

Boarnet, M., Day, K., Anderson, C., McMillan, T. and Alfonzo, M. (2005*b*) California's Safe

Routes to School Program: impacts on walking, bicycling, and pedestrian safety. *Journal of the American Planning Association*, **71**(3), pp. 301–317.

Brownson, R.C., Hagood, L., Lovegreen, S.L., Britton, B., Caito, N.M., Elliott, M.B., Emery, J., Haire-Joshu, D., Hicks, D., Johnson, B., McGill, J.B., Morton, S., Rhodes, G., Thurman, T. and Tune, D. (2005) A multilevel ecological approach to promoting walking in rural communities. *Preventive Medicine*, **41**(5/6), pp. 837–842.

Cao, X., Mokhtarian, P. and Handy, S. (2009) Examining the impacts of residential self-selection on travel behaviour: a focus on empirical findings. *Transport Reviews*, **29**(3), pp. 359–395.

CDC (Centers for Disease Control and Prevention) (2005) Barriers to children walking to or from school – United States, 2004. *Morbidity and Mortality Weekly Report*, **54**(38), pp. 949–952.

Cervero, R., and Duncan, M. (2003) Walking, bicycling, and urban landscapes: evidence from the San Francisco Bay Area. *American Journal of Public Health*, **93**(9), pp. 1478–1483.

Chen, A.H., Sallis, J.F., Castro, C.M., Lee, R.E., Hickmann, S.A., William, C. and Martin, J.E. (1998) A home-based behavioral intervention to promote walking in sedentary ethnic minority women: project WALK. *Womens Health*, **4**(1), pp. 19–39.

Clarke, K.K., Freeland-Graves, J., Klohe-Lehman, D.M., Milani, T.J., Nuss, H.J. and Laffrey, S. (2007) Promotion of physical activity in low-income mothers using pedometers. *Journal of the American Dietetic Association*, **107**(6), pp. 962–967.

Crane, R. (2000) The influence of urban form on travel: an interpretative review. *Journal of Planning Education and Research*, **15**(1), pp. 3–23.

Davison, K.K. and Lawson, C.T. (2006) Do attributes in the physical environment influence children's physical activity? A review of the literature. *International Journal of Behavioral Nutrition and Physical Activity*, **3** Available at: http://www.ijbnpa.org/content/3/1/19. Accessed 6 October 2010.

DfT (Department for Transport) (2006) *Personalized Travel Planning: Evaluation of 14 Pilots Part Funded by DfT*. London: DfT. Available at http://www.dft.gov.uk/pgr/sustainable/travelplans/ptp/personalisedtravelplanningev5774. Accessed 6 October 2010.

Dill, J. (2009) Bicycling for transportation and health: the role of infrastructure. *Journal of Public Health Policy*, **30**, pp. S95–S110.

Dill, J., and Carr, T. (2003) Bicycle commuting and facilities in major U.S. Cities: if you build them, commuters will use them. *Transportation Research Record* No. 1828, pp. 116–123.

Dinger, M.K., Heesch, K.C. and McClary, (K.R. 2005) Feasibility of a minimal contact intervention to promote walking among insufficiently active women. *American Journal of Health Promotion*, **20**(1), pp. 2–6.

Dumbaugh, E. and Frank, L.D. (2007) Traffic Safety and Safe Routes to Schools: Synthesizing the Empirical Evidence, in *Transportation Research Board 86th Annual Meeting*. Washington DC: Transportation Research Board.

Ewing, R. and Cervero, R. (2001) Travel and the built environment: a synthesis. *Transportation Research Record*, No. 1780, pp. 87–112.

Ewing, R., Schroeer, W. and Greene, W. (2004) School Location and Student Travel: Analysis of Factors Affecting Mode Choice, in Transportation Research Board 83rd Annual Meeting. Washington DC: Transportation Research Board.

Ewing, R. and Dumbaugh, E. (2009) The built environment and traffic safety: a review of empirical evidence. *Journal of Planning Literature*, **23**(4), pp. 347–367.

Ewing, R., Bartholomew, K., Winckelman, S. and Walters, J. (2008) *Growing Cooler: Evidence on Urban Development and Climate Change*. Washington, DC: Urban Land Institute.

Ewing, R. and Cervero, R. (2010) Travel and the built environment: a meta-analysis. *Journal of the American Planning Association*, **76**(3), pp. 1–30.

Ferreira, I., van der Horst, K., Wendel-Vos W., Kremers, S., van Lenthe, F.J. and Brug, J. (2007) Environmental correlates of physical activity in youth – a review and update. *Obesity Reviews*, **8**(2), pp. 129–154.

Forester, J. (1994) *Bicycle Transportation: A Handbook for Cycling Transportation Engineers*. Cambridge, MA: MIT Press.

Forester, J. (2001) The bikeway controversy. *Transportation Quarterly*, **55**(2), pp. 7–17.

Forsyth, A., Oakes, J.M., Schmitz, K.H. and Hearst, M. (2007) Does residential density increase walking and other physical activity? *Urban Studies*, **44**(4), pp. 679–697.

Forsyth, A., Hearst, M., Oakes, J.M. and Schmitz,

K.H. (2008) Design and destinations: factors influencing walking and total physical activity. *Urban Studies*, **45**(9), pp. 1973–1996

Forsyth, A., Krizek, K. and Rodriguez, D. (2009*a*) Non-motorized travel research and contemporary planning initiatives. *Progress in Planning*, **71**, pp. 170–184.

Forsyth, A., Oakes, J.M., Lee, B. and Schmitz, K.H. (2009*b*) The built environment, walking, and physical activity: is the environment more important to some people than others? *Transportation Research D*, **14**, pp. 42–49.

Gebel, K., Bauman, A.E. and Petticrew, M. 2007) The physical environment and physical activity a critical appraisal of review articles. *American Journal of Preventive Medicine*, **32**(5), pp. 361–369.

Giles-Corti, B. and Salmon, J. (2007) Encouraging children and adolescents to be more active. *British Medical Journal*, **335**, pp. 677–678.

Giles-Corti, B. Kelty, S.F., Zubricj, S.R. and Villanueva, K.P. (2009) Encouraging walking for transport and physical activity in children and adolescents: How important is the built environment. *Sports Medicine*, **39**(12), pp. 995–1009.

Goulias, K.G., Broeg, W.W., James, B. and Graham, C. (2002) Travel behavior analysis of South Perth individualized marketing intervention. *Transportation Research Record*. No.1807, pp. 77–86.

Green, L.W., C. Orleans, J. Ottoson *et al*. (2006) Inferring strategies for disseminating physical activity policies, programs, and practices from the successes of tobacco control. *American Journal of Preventive Medicine*, **31**(Suppl 4), pp. S66–S81.

Hallett, I., Luskin, D. and Machemehl, R. (2006) *Evaluation of On-Street Bicycle Facilities Added to Existing Roadways*. Austin, TX: Centre for Transportation Research, University of Texas. Available at: http://www.utexas.edu/research/ctr/pdf_reports/0_5157_1.pdf. Accessed 6 October 2010.

Handy, S. (2004) Critical Assessment of the Literature on the Relationship Among Transportation, Land Use, and Physical Activity. Paper prepared for the Transportation Research Board and the Institute of Medicine Committee on Physical Activity, Health, Transportation, and Land Use, Washington DC.

Handy, S. and Clifton, K.J. (2001) Local shopping as a strategy for reducing automobile dependence. *Transportation*, **28**, pp. 317–346.

Harkey, D.L. and Stewart, J.R. (1997) Evaluation of shared-use facilities for bicycles and motor vehicles. *Transportation Research Record*, No. 1578, pp. 111–118.

Heath, G.W., Brownson, R.C., Kruger, J., Miles, R., Powell, K.E. and Ramsey, L.T. (2006) The effectiveness of urban design and land use and transport policies and practices to increase physical activity: a systematic review. *Journal of Physical Activity and Health*, **3**(1), pp. S55–S76.

Heinen, E., van Wee, B. and Maat, K. (2010) Commuting by bicycle: an overview of the literature. *Transport Reviews*, **30**(1), pp. 59–96

Hoehner, C.M., Ramirez, L.B., Elliott, M.B., Handy, S. and Brownson, R.C. (2005) Perceived and objective environmental measures and physical activity among urban adults. *American Journal of Preventive Medicine*, **28**, pp. 105–116.

Humpel, N., N. Owen, and E. Leslie (2002) Environmental factors associated with adults' participation in physical activity: A review. *American Journal of Preventive Medicine*, **22**(3), pp. 188–199.

Hunter, W. W., J. R. Feaganes, and R. Srinivasan (2005) Conversion of Wide Curb Lanes: The Effect on Bicycle and Motor Vehicle Interactions. *Transportation Research Record* 1939, pp. 37–44.

Hunter, W.W., Stewart, J.R., and Stutts, J.C. (1999) Study of bicycle lanes versus wide curb lanes. *Transportation Research Record*, No. 1674, pp. 70–77.

Iacono, M., Krizek, K.J. and El-Geneidy, A. (2008) *Access to Destinations: How Close is Close Enough? Estimating Accurate Distance Decay Functions for Multiple Modes and Different Purposes*. Report MN/RC 2008-11 St. Paul, MN: Minnesota Department of Transportation.

Jacobsen, P.L. (2003) Safety in numbers: more walkers and bicyclists, safer walking and bicycling. *Injury Prevention*, **9**, pp. 205–209.

Jilcott, S. B., Evenson, K. R., Laraia, B. A., & A. S. Ammerman (2007) Association between physical activity and proximity to physical activity resources among low-income, midlife women. *Preventing Chronic Disease*, **4**(1). Available at: http://www.cdc.gov/pcd/issues/2007/jan/06_0049.htm. Accessed 6 October 2010.

Krizek, K. (2006) Two approaches to valuing some of bicycle facilities' presumed benefits. *Journal of the American Planning Association*, **72**(3), pp. 309–320.

Krizek, K.J., Johnson, P.J. and Tilahun, N. (2005)

Gender Differences in Bicycling Behavior and Facility Preferences. Volume 2. *Research on Women's Issues in Transportation*. Washington DC: National Academy Press/Transportation Research Board, Special Report, pp. 31–40.

Krizek, K.J. and Johnson, P.J. (2006) Proximity to trails and retail: Effects on urban cycling and walking. *Journal of the American Planning Association*, **72**(1), pp. 33–42.

Krizek, K., Poindexter G., Barnes, G. and Mogush, P. (2007) Analysing the benefits and costs of bicycle facilities via online guidelines. *Planning Practice and Research*, **22**(2), pp. 197–213.

Krizek, K., Forsyth, A. and Baum, L. (2009*a*) *Walking and Cycling International Literature Review*. Melbourne: Victoria Department of Transport.

Krizek, K., Handy, S. and Forsyth, A. (2009*b*) Explaining changes in walking and bicycling behavior: challenges for transportation research. *Environment and Planning B*, **36**, pp. 725–740.

Lee, C. and Moudon, A.V. (2006) Correlates of walking for transportation or recreation purposes. *Journal of Physical Activity and Health*, **3**(Suppl 1), pp. S77–S98. Available at http://www.activelivingresearch.org/alr/files/JPAH_6_Lee.pdf. Accessed 6 October 2010.

Marshall, W. and Garrick, N. (2010) Evidence on Why Bike-Friendly Cities are Safer for all Road Users. Working paper from authors.

Martens, K. (2004) The bicycle as a feedering mode: experiences from three European countries. *Transportation Research D*, **9**(4), pp. 281–294.

McGinn, A.P., Evenson, K.R., Herring, A.H. and Huston, S.L. (2007) The relationship between leisure, walking, and transportation activity with the natural environment. *Health & Place*, **13**(3), pp. 588–602.

Merom, D., Bauman, A., Vita, P. and Close, G. (2003) An environmental intervention to promote walking and cycling – the impact of a newly constructed rail trail in Western Sydney. *Preventive Medicine*, **35**(2), pp. 235–242.

Moudon, A.V., Lee, C., Cheadle, A.D., Collier, C.W., Johnson, D., Schmid, T.L. and Weather, R.D. (2005) Cycling and the built environment, a U.S. perspective. *Transportation Research D*, **10**, pp. 245–261.

Mutrie, N., Carney, C., Blamey, A., Crawford, F., Aitchison, T. and Whitelaw, A. (2002) Walk in to work out: a randomised controlled trial of a self help intervention to promote active commuting. *Journal of Epidemiology & Community Health*, **56**(6), pp. 407–412.

Naumann, R., Dellinger, A., Anderson, M., Bonomi, A., Rivara, F. and Thompson, R. (2009) Preferred modes of travel among older adults: what factors affect the choice to walk instead of drive? *Journal of Safety Research*, **40**, pp. 395–398.

Noland, R.B. and Ishaque, M.M. (2006) Smart bicycles in an urban area: evaluation of a pilot scheme in London. *Journal of Public Transportation*, **9**(5), pp. 71–95.

Ogilvie, D., Egan, M., Hamilton, V. and Petticrew, M. (2004) Promoting walking and cycling as an alternative to using cars: systematic review. *British Medical Journal*, **329**, pp. 763–767.

Ogilvie, D., Foster, C.E., Cavill, N., Hamilton, V. and Fitzsimons, C.F. (2007) Interventions to promote walking: systematic review. *British Medical Journal*, **334**, pp. 1204–1213.

Olszewski, P. and Wibowo, S.S. (2005) Using equivalent walking distance to assess pedestrian accessibility to transit stations in Singapore. *Transportation Research Record*, No. 1927, pp. 38–45.

Oregon Department of Transportation (1995) *Oregon Bicycle and Pedestrian Plan*. Salem, OR: Oregon Department of Transportation.

Owen, N., Humpel, N., Leslie, E., Bauman, A. and Sallis, J.F. (2004) Understanding environmental influences on walking; Review and research agenda. *American Journal of Preventive Medicine*, **27**(1), pp. 67–76.

Pedler, A. and Davies, D.G. (2000) *Cycle Track Crossings of Minor Roads*. Crowthorne: TRL Limited.

Pucher, J. (1988) Urban travel behavior as the outcome of public policy: the example of modal-split in Western Europe and North America. *Journal of the American Planning Association*, **54**(4), pp. 509–520.

Pucher, J. (2001) Cycling safety on bikeways vs. roads. *Transportation Quarterly*, **55**(4), pp. 9–11.

Pucher, J. and Buehler, R. (2008) Making cycling irresistible: lessons from the Netherlands, Denmark, and Germany. *Transport Reviews*, **28**, pp. 495–528.

Pucher, J., Dill, J. and Handy, S. (2010) Infrastructure, programs, and policies to increase bicycling: an international review. *Preventive Medicine*, **50**, pp. S106–S125.

Räsänen, M. and Summala, H. (1998) Attention and expectation problems in bicycle-car collisions: an in-depth study. *Accident Analysis & Prevention*, **30**(5), pp. 657–666.

Reger, B., Cooper, L., Booth-Butterfield, S., Smith,

H., Bauman, A., Wootan, M., Middlestadt, S., Marcus, B. and Greer, F. (2002) Wheeling walks: a community campaign using paid media to encourage walking among sedentary older adults. *Preventive Medicine*, **35**(3), pp. 285–292.

Rodriguez, D., Aytur, S., Forsyth, A., Oakes, J.M. and Clifton, K. (2007) Relation of modifiable neighborhood attributes to walking. *Preventive Medicine*, **47**, pp. 260–264.

Saelens, B.E., Sallis, J.F. and Frank, L.D. (2003) Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. *Annals of Behavioral Medicine*, **25**(2), pp. 80–91.

Saelens, B. and Handy, S. (2008) Built environment correlates of walking: a review. *Medicine & Science in Sports & Exercise*, **40**, pp. S550–S566.

Shoup, D.C. (2005) *The High Cost of Free Parking*. Chicago, IL: APA Planners Press.

Summala, H., Pasanen, E., Räsänen, M. and Sievänen, J. (1996) Bicycle accidents and drivers' visual search at left and right turns. *Accident Analysis & Prevention*, **28**(2), pp. 147–153.

Taylor, M.A.P. (2007) Voluntary travel behavior change programs in Australia: the carrot rather than the stick in travel demand management. *International Journal of Sustainable Transportation*, **1**(3), pp. 173–192.

Timperio, A., Crawford, D., Telford, A. and Salmon, J. (2004) Perceptions about the local neighborhood and walking and cycling among children. *Preventive Medicine*, 38(1), pp. 39–47.

Timperio, A., Ball, K., Salmon, J., Roberts, R., Giles-Corti, B., Simmons, D., Baur, L.A. and Crawford, D. (2006) Personal, family, social, and environmental correlates of active commuting to school. *American Journal of Preventive Medicine*, **30**(1), pp. 45–51.

Transportation Research Board (2009) *Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO_2 Emissions*. Special Report 298. Washington DC: The National Academies.

Trost, S., Owen, N., Bauman, A., Sallis, J.F. and Brown, W. (2002) Correlates of adults' participation in physical activity: review and update. *Medicine Science and Sports Exercise*, **34**(12), pp. 1996–2001.

van Lenthe, F.J., Brug, J. and Mackenbach, J.P. (2005) Neighborhood inequalities in physical inactivity: the role of neighborhood attractiveness, proximity to local facilities and safety in the Netherlands. *Social Science and Medicine*, **60**(4), pp. 763–775.

Van Wee, B. (2002) Land use and transport: research and policy challenges. *Journal of Transport Geography*, **10**(4), pp. 259–271.

Wachtel, A. and Lewiston, D. (1994) Risk factors for bicycle-motor vehicle collisions at intersections. *ITE Journal*, **64**(9), pp. 30–35.

Wendel-Vos, W., Droomers, M., Kremers, S., Brug, J. and van Lenthe, F. (2007) Potential environmental determinants of physical activity in adults: a systematic review. *Obesity Reviews*, **8**(5), pp. 425–440.

Williams, D., Matthees, C., Rutt, C., Napolitano, M. and Marcus, B. (2008) Interventions to increase walking behaviour. *Medicine and Science in Sports and Exercise* **40**, pp. S567–S573.

Xing, Y., Handy, S. and Mokhtarian, P. (2010) Factors associated with proportions and miles of bicycling for transportation and recreation in six small U.S. cities. *Transportation Research D*, **15**, pp. 73–81.

Zeeger, C. (1998) *Design and Safety of Pedestrian Facilities*. Washington DC: Institute of Traffic Engineers.

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