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Abstract

Walking and cycling are the healthiest ways to get around our cities, providing valuable physical activity for people on a daily basis. These forms of active transport also generate indirect public health benefits by reducing the use of automobiles, thus diminishing air, water, and noise pollution and the overall level of traffic danger. This paper provides a broad overview of the role walking and cycling can play in making our cities healthier. First, we summarize the scientific evidence of the health benefits of walking and cycling. Second, we examine variations in walking and cycling levels in Europe, North America, and Australia. Third, we consider the crucial issue of traffic safety. Finally, we describe a range of government policies needed to encourage more walking and cycling: safe and convenient infrastructure such as sidewalks, crosswalks, bike paths and lanes, and intersection crossings; traffic calming of residential neighborhoods; integration with public transport; land-use policies that foster compact, mixed-use developments; people-friendly urban design; improved traffic education; strict enforcement of traffic regulations; and reductions in motor vehicle speed limits.

The European Union and the USA have officially recognized the importance of walking and cycling as practical modes of urban transport and endorse the dual objectives of raising walking and cycling levels while increasing their safety (CEMT, 2004; European Commission, 2007; USDOT, 1994, 2004). There are many reasons to encourage more walking and cycling. They cause virtually no noise or air pollution and consume far less nonrenewable resources than any motorized transport mode. The energy walking and cycling require is provided directly by the traveler, and the very use of that energy offers valuable cardiovascular exercise. Walking and cycling take up a small fraction of the space needed for the use and parking of cars. Moreover, walking and cycling are economical, costing far less than the private car and public transport, both in direct user outlays and public infrastructure investments. Because they are affordable by virtually everyone, walking and cycling are probably the most equitable of all transport modes. In short, it is hard to beat walking and cycling when it comes to environmental, economic, and social sustainability.

This paper provides an update and synthesis of the authors' previous work on walking and cycling (Pucher, 1997; Pucher et al., 1999; Pucher and Dijkstra, 2000; Pucher and Dijkstra, 2003; Pucher and Buehler, 2006; Pucher and Buehler, 2007; Pucher and Buehler, 2008; Bassett et al., 2008; Pucher et al., 2010a; Pucher et al., 2010b). We also examine recently published research on each of four aspects of walking and cycling: health benefits; variation among countries; traffic safety; and government policies. Our purpose is not to provide an in-depth analysis of any particular issue but to offer a broad overview of how cycling and walking can contribute to healthier cities.

Health Benefits of Walking and Cycling

The importance of physical activity for public health is well established (Donnelly et al., 2000; Haskell et al., 2007; USDHHS, 1996, 2008; WHO, 2002a, b). Although earlier studies did not focus on walking and cycling, they found that even 30 minutes per day of moderate-intensity physical activity, if performed on a regular basis, have significant health benefits. More recent studies have specifically examined walking and cycling for daily travel and find that they provide valuable physical activity and significant health benefits. Huy et al. (2008) found that walking and cycling for transport are directly related to improved health in older adults. The Coronary Artery Risk Development in Young Adults (CARDIA) study found that active commuting was positively associated with aerobic fitness in men and women, and inversely associated with obesity, triglyceride levels, resting blood pressure, and fasting insulin in men (Gordon-Larsen et al., 2009).

Further evidence of the link between active commuting and health is provided by a review of prospective, longitudinal studies (Hamer and Chida, 2008). Matthews et al. (2007) examined over 67,000 Chinese women in the Shanghai women's health study and followed them

for an average of 5.7 years. Women who walked and cycled for transport had reduced rates of all-cause mortality, compared to those who did not walk or cycle. Similarly, Andersen et al. (2000) observed that cycling to work decreased mortality rates by 40% in Danish men and women. A recent analysis of a multi-faceted cycling demonstration project in Odense, Denmark reported a 20% increase in cycling from 1996 to 2002 and a 5-month increase in life expectancy for males (Cykelby, 2010). A Dutch study found that health benefits of cycling greatly exceed the health risks from traffic injuries (de Hartog et al, 2010). Expressing mortality impacts as life years gained or lost, the study estimated a range of 3-14 months gained by an individual shifting from the car to the bicycle for short trips compared to 5-9 days lost due to the risk of traffic crashes. A 16-year follow-up study of 18,414 premenopausal women in the USA found significantly less weight gain among those engaged in brisk walking and cycling (Lusk et al., 2010).

The contribution of walking and cycling to fighting the obesity epidemic is confirmed by international comparisons of obesity rates with levels of walking and cycling for daily travel. As shown by several studies, there is a striking inverse correlation between obesity and active transport (Bassett et al., 2008; Alliance for Biking and Walking, 2010; Pucher et al., 2010b). Countries such as the Netherlands, Sweden, and Denmark, which have high rates of walking and cycling, tend to have lower rates of obesity. Countries such as the USA, Australia, and Canada, which have low rates of walking and cycling, tend to have much higher rates of obesity. Higher levels of active transport in the Netherlands, Sweden, and Denmark may also contribute to longer life expectancy as well as longer healthy life expectancy—two years longer than in the USA (OECD, 2008; WHO, 2008a).

Although obesity rates in Europe are generally lower than those in North America and Australia, they have been rising in almost all OECD countries, including those in Europe (IOTF, 2010; OECD, 2009). In every OECD country, rates of car ownership and use have increased sharply over the past few decades, while rates of walking and cycling have fallen (Banister, 2005; Fietsberaad, 2006, 2010; International Road Federation, 2007; OECD, 2004). Increasing car dependence may help explain the increasing rates of obesity in OECD countries, just as the higher levels of car dependence may help explain the current, higher rates of obesity in North America and Australia compared to Europe. Of course, these correlations do not prove that car dependence causes obesity, but they are at least consistent with that hypothesis. Moreover, the public health literature provides evidence that there is a causal link between rising motorization and the worsening obesity epidemic (Bell et al., 2001).

The mounting body of evidence on the health benefits of active travel has led government agencies, public health organizations, and medical journals to advocate more walking and cycling as a way to improve individual health as well as reduce air pollution, carbon emissions, congestion, noise, traffic dangers, and other harmful impacts of car use (BMA, 1992; Carnall, 2001; Cavill et al., 2006; CEMT, 2004; Dora and Phillips, 2000; Godlee, 1992; Hillman, 1993; IOTF, 2002, 2010; Koplan and Dietz, 1999; USDHHS, 1996, 2008; USDOT, 1994, 2004; WHO, 2002a, b).

Variation in Walking and Cycling Levels

As shown in Figure 1, there are large differences among countries in the share of daily trips made by walking and cycling. At the lower end of spectrum, only about a tenth of daily trips are by foot or bike in car-oriented countries such as Australia, Canada, and the USA. At the other end of the spectrum, over half of all daily trips in the Netherlands are by walking or

cycling. Most European countries are in between, with active transport accounting for 25%-35% of daily trips.

[Figure 1 here]

The percentages reported in Figure 1 are not entirely comparable. For most of the countries shown, the modal share refers to daily trips for all trip purposes, as derived from national travel surveys. Australia, Canada, and Ireland, however, do not have national travel surveys, and their Censuses only report on trips to work. Walking and cycling rates are generally higher for non-work trips than for work trips. Thus, Census data probably underestimate overall levels of walking and cycling. That is seen most clearly by comparing the two 2008 surveys for the USA. The U.S. Census Bureau's American Community Survey (ACS), which only includes work trips, reports only a third as high a bike/walk share (3.5% vs. 12%) as the National Household Travel Survey, which includes all trip purposes. There are also methodological differences in the travel surveys for the various countries that limit their comparability. Nevertheless, it is clear that European countries have active transport rates at least twice as high as in North America and Australia.

Trends in Walking and Cycling

Active travel has generally declined in OECD countries over the last four decades. Figure 2 shows trends from national travel surveys of six countries. The most dramatic change has been the falling share of trips by walking. As shown in Figure 2, the modal share of walking fell by roughly half in both France and the UK, by a third in Germany, and by a fourth in Denmark. Only in the Netherlands did walking levels remain stable. The bike share of trips fell by half in the UK, by a third in France, and by a tenth in the Netherlands, while it increased slightly in Germany and Denmark. The combined modal shares of walking and cycling in the

early 1970s were roughly comparable in the five European countries shown in Figure 2 (about 40-50%), but the most recent surveys indicate a level of active travel in the Netherlands, Denmark, and Germany that is almost twice as high as in France and the UK.

The much smaller declines in active transport in the Netherlands, Denmark, and Germany might be attributable to more car-restrictive policies in those countries since the 1970s, combined with a wide range of measures to encourage more walking and cycling, as described later in this article. Car-restrictive measures have been far less common in France and the UK, and those two countries have also done less to promote walking and cycling through infrastructure, programs, and policies (Banister, 2005; Hass-Klau, 1990; Pucher and Buehler, 2008a; Tolley, 2003). In addition, studies suggest that suburban and exurban sprawl has been more extensive in France and the UK than in the Netherlands, Denmark, and Germany (EEA, 2006; Pucher and Lefevre, 1996; TRB 2001).

It is more difficult to gauge walking and cycling trends in the USA because there was an important change in the national travel survey methodology in 2001 that raised the walk mode share by capturing previously unreported walk trips. The survey results in Figure 2 suggest slight increases in walking and cycling levels in the USA, but in fact, they have probably declined. For example, the US Census, using a consistent methodology over time, reports a substantial decline in walking and cycling to work: from 7.9% in 1970 to only 3.3% in 2008 (USDOC, 2010).

Trends in walking and cycling have diverged in some countries. In Germany, for example, the share of trips on foot fell from 34% to 24%, while cycling increased from 9% to 10% of all trips. Similarly, in Denmark walking declined from 21% to 16% of trips, while cycling rose from 17% to 18%. The growing size and decentralization of urban areas have

generated increasing trip distances in most countries, which may help explain the decline in walking, in particular. Because cycling can cover longer trip distances than walking, it may have benefited somewhat from the shift from short to medium-distance trips. Thus, there may have been some substitution of cycling for walking over the lower range of trip distances. The growth in long trips, however, clearly deters cycling as well, and that impact has dominated in most countries.

[Figure 2 here]

Role of Trip Distance

To some extent, the higher walking and cycling rates in Europe are due to the shorter trip distances in European cities, which tend to be older, more compact, and characterized by more mixing of commercial and residential land uses (Banister, 2005; Ewing and Cervero, 2001; Newman and Kenworthy, 1999; Pucher, 1995a, b; Pucher and Buehler, 2008a; TRB, 2001). Even controlling for trip distance, however, Europeans make a far higher percentage of their trips by walking and cycling. As shown in Figure 3, the percentage of trips by active transport in Germany, Denmark, and the Netherlands is much higher than in the USA within each of the three trip distance categories. The biggest difference, however, is for trips between 2.5km and 6km. Over that distance, the share of walking and cycling trips in the USA is only a fourth to a sixth as high as in Germany, Denmark, and the Netherlands.

[Figure 3 here]

Differences by Gender

There are large differences among countries in cycling rates between men and women. In the USA, Canada, and the UK, women account for only about a fourth of all bike trips compared to roughly half of all bike trips in Germany, Denmark, and the Netherlands. While

cycling is gender-neutral in Germany, Denmark, and the Netherlands, it is dominated by men in the USA, Canada, and the UK. That is consistent with other research that finds a strong positive correlation between a country's or city's share of trips made by bike and the percentage of bike trips made by women (Garrard et al., 2008; Geddes, 2009; Pucher and Buehler, 2008a; Pucher et al., 2010a). Indeed, one researcher has suggested that women are an "indicator species" for cycling: Where many women cycle, it means that cycling is safe and convenient for everyone, leading to a high overall bike mode share (Baker, 2009). Studies show that women strongly prefer bike paths and cycle tracks that are physically separated from motor vehicle traffic, and that cycling rates among women are higher in cities with such traffic-protected facilities (Garrard et al., 2008). In contrast to cycling, there is little variation among countries in the share of walk trips made by women.

Differences by Age Group

Walking and cycling levels can vary significantly by age, but the variation is much less in some countries than in others. As shown in Figure 4, both walking and cycling increase with age in the Netherlands, Denmark, and Germany. In the Netherlands, for example, the total share of bike and walk trips rises from 40% in the age category 26-44 to 51% in the age category 65+. Similarly, the combined share of walk and bike trips in Germany rises from 24% in the age category 18-15 to 41% in the age category 65+. The same pattern holds for Denmark, with the share of walk and bike trips rising from 27% in the age category 30-39 to 36% in the age category 70-84. Walking and cycling account for roughly half of all trips by the Dutch, German, and Danish elderly, compared to only a fifth of the trips by the British elderly and only a tenth of trips made by the American elderly.

[Figure 4 here]

Differences among countries in rates of cycling are especially striking. The cycling share of trips made by the elderly is 23% in the Netherlands, 15% in Denmark, and 10% in Germany. That compares to only 1% in the UK and 0.5% in the USA. As discussed later in this paper, the much better cycling facilities in the Netherlands, Denmark, and Germany help explain the high levels of cycling by the elderly in those three countries (Pucher and Buehler, 2008a). Similar to women, the elderly are especially sensitive to traffic dangers and strongly prefer separate facilities that give them more protection from motor vehicle traffic.

The much higher rates of walking and cycling among the Dutch, Danish, and German elderly not only provide them with valuable physical exercise but also enhance their mobility and independence that improve their quality of life. As the Dutch, Danish, and German examples clearly show, the physical and mental limitations that come with aging are not the main impediments to walking and cycling by the American elderly. The really important deterrents to walking and cycling in the USA—for all age groups, but especially for the elderly—are the unsafe and inconvenient walking and cycling conditions in most American cities (Pucher and Dijkstra, 2003; Pucher and Buehler, 2008a; STPP, 2004).

Walking and Cycling Safety

Many studies show that traffic danger is a significant deterrent to walking and cycling, especially for women, children, and the elderly (Alliance for Biking and Walking, 2010; IRTAD, 2008; McClintock, 2002; OECD, 2007; Pucher and Dijkstra, 2003; Tolley, 2003; USDOT, 1994, 2004; WHO, 2002a). Thus, one reason for the lower rates of walking and cycling in the USA may be the much greater dangers faced by pedestrians and cyclists there. As shown in Figure 5, cyclist fatalities per km cycled are 3-5 times higher in the USA than in the Netherlands, Denmark, and Germany. Walking in the USA is even more dangerous, with pedestrian fatalities

per km that are 5-6 times higher than in the Netherlands, Denmark, and Germany. Walking and cycling are about twice as dangerous in the UK as in Germany, but still much less dangerous than in the USA. Pedestrian and cyclist non-fatal injury rates are also much higher in the USA, with roughly the same ranking in traffic safety among countries as shown by the fatality rates.

[Figure 5 here]

Safety Trends

Walking and cycling were not always as safe in northern Europe as they are today. As noted later in this article, many European countries implemented a coordinated range of policies to improve conditions for pedestrians and cyclists. The results were impressive. As shown in Figure 6, annual cyclist fatalities in the Netherlands, Denmark, Germany, and the UK fell by 60%-80% from 1970 to 2008. By comparison, cyclist fatalities fell by less than 10% in the USA, and almost all of that was due to a sharp decline in children cycling (Pucher et al., 1999; USDOT, 2010). Similarly, part of the drop in cyclist fatalities in the UK was due to a falling bike mode share and a decline in the number of trips over the same period. The reverse was the case in Denmark and Germany, where cycling fatalities fell in spite of a growing bike mode share and an increasing number of bike trips (Pucher and Buehler, 2008a). As seen in Figure 2, the modal share of cycling fell slightly in the Netherlands, but the total number of bike trips actually increased.

[Figure 6 here]

In all five countries, pedestrian fatalities have fallen even more than cyclist fatalities. Even in the USA, pedestrian fatalities fell by half from 1970 to 2008. In the UK and Denmark, pedestrian fatalities fell by about 80%, and in Germany and the Netherlands, they fell by an impressive 90%. Since walking levels fell in all five countries over this period, part of the

reduction in fatalities is simply due to reduced exposure rates. But as with cyclist fatalities, the improvement in pedestrian safety has been much greater in Europe than in the USA, with especially impressive gains in Germany and the Netherlands. In summary, walking and cycling are much safer in northern Europe than in the USA, and safety has improved much more in northern Europe than in the USA over the past four decades.

[Figure 7 here]

Safety in Numbers

The discussion so far suggests that traffic safety has an important impact on walking and cycling and that greater safety in the Netherlands, Denmark, and Germany helps explain their higher walking and cycling rates. But causation may also run in the other direction: more walking and cycling may help improve safety. Several studies have demonstrated the principle of "safety in numbers" (Elvik, 2009; Jacobsen, 2003; Jacobsen et al., 2009; Robinson, 2005). Using both time-series and cross-sectional data, they find that walking and cycling safety is greater in countries and cities with higher levels of walking and cycling, and that pedestrian and cyclist injury rates fall as levels of walking and cycling increase. As the number of pedestrians and cyclists grows, they become more visible to motorists, which is a crucial factor in walking and cycling safety. Motorists may also become more used to the sometimes unpredictable moves by pedestrians and cyclists (which are thus less unexpected) and better prepared to avoid collisions. In addition, a higher percentage of motorists are likely to be pedestrians or cyclists themselves, and thus more sensitive to the needs and rights of pedestrians and cyclists. Finally, the presence of large numbers of pedestrians and cyclists may help underpin their legal use of roadways and intersection crossings and generate public and political support for more investment in walking and cycling infrastructure.

Whatever the direction of causation, there is a strong correlation between walking and cycling levels and safety rates, as revealed by a comparison of Figure 1 and Figure 5. Moreover, all studies agree on the importance of improving traffic safety to encourage more walking and cycling. The greatly improved safety of walking and cycling in Germany, Denmark, and the Netherlands can be explained by a wide range of programs and policies specifically designed to encourage walking and cycling and walking while restricting car use.

Policies to Promote Safe Walking and Cycling

There are many ways to encourage more walking and cycling while at the same time making them safer ways to get around our cities. As shown by the wide range of coordinated policies implemented in The Netherlands, Germany, and Denmark since the early 1970s, the necessary techniques and programs already exist and have been proven to work well. With each passing decade, conditions for walking and cycling in those three countries have improved. The integrated package of measures includes the following categories:

- Better infrastructure for walking and cycling
- Traffic calming of residential neighborhoods
- Integration of walking and cycling facilities with public transport
- Land-use policies that encourage compact developments and mixing of residential and commercial uses
- Urban design sensitive to the needs of non-motorists
- Rigorous traffic education of both motorists and non-motorists;
- Strict enforcement of traffic regulations protecting pedestrians and bicyclists
- Complementary roadway, parking, and taxation policies

Due to space limitations, these eight categories of public policy measures are only briefly summarized here. For detailed descriptions and illustrations of the European policies to encourage walking and cycling, readers can consult a range of publications: Dutch Cycling Council (2006); ECMT (2004); Fietsberaad (2006, 2010); Hass-Klau (1990, 1993); McClintock (2002); Netherlands Ministry of Transport (2006); Newman and Kenworthy (1999); Pucher and Dijkstra (2000); Pucher and Buehler (2007, 2008a); Pucher et al. (2010a); Tolley (2003); USDOT (1994, 2004); and Zegeer (1994).

Safe and Convenient Facilities for Walking and Cycling

One emphasis of Dutch, Danish, and German policy has been to improve the transportation infrastructure needed for walking and cycling. For pedestrians, that has included extensive auto-free zones that cover much of the city center; wide, well-lit sidewalks on both sides of every street; pedestrian refuge islands for crossing wide streets; clearly-marked zebra crosswalks, often raised and with special lighting for visibility; and pedestrian-activated crossing signals, both at intersections and mid-block crosswalks (Pucher and Dijkstra, 2000).

[Figure 8 here]

Especially from the mid-1970s to the mid-1990s, separate facilities such as bike paths and lanes expanded greatly in most northern European countries. In Germany, for example, the bikeway network almost tripled in length, from 12,911km in 1976 to 31,236km in 1996 (Bundesregierung, 1998). In the Netherlands, the bikeway network doubled in length, from 9,282km in 1978 to 18,948km in 1996 (Pucher and Dijkstra, 2000; Statistics Netherlands, 1999). Nationwide, aggregate statistics for the period since the mid 1990s are not available, but data for individual cities suggest continued expansion, albeit at a much slower rate than previously

(Pucher and Buehler, 2007). The main focus now is on improving the specific design of cycle paths and lanes to improve safety, especially at intersections.

[Figure 9 here]

In addition, there are an increasing number of so-called "bicycle streets," where cars are permitted but cyclists have priority over the entire breadth of the roadway. Unlike the sparse and fragmented cycling facilities in the USA, the bike paths, lanes, and streets in the Netherlands, Denmark, and Germany form a truly coordinated network covering both rural and urban areas. Importantly, Dutch, Danish, and German bikeway systems serve practical destinations for everyday travel, not just recreational attractions, as most bike paths in the USA.

[Figure 10 here]

The provision of separate rights-of-way is complemented by various other measures: special bike lanes leading directly to and through intersections; separate bike traffic signals with advance green lights for cyclists; bicyclist-activated traffic signals at key intersections; and modification of street networks to create deliberate dead ends and slow, circuitous routing for cars but direct, fast connections for bikes (Pucher and Buehler, 2007, 2008a, b).

Traffic Calming of Residential Neighborhoods

Traffic calming limits the volume and speed of motor vehicle traffic, both by law—30 km per hour (19mph) or less—and through physical barriers such as raised intersections and crosswalks, traffic circles, road narrowing, zigzag routes, curves, speed humps, and artificial dead-ends created by mid-block street closures (Pucher and Dijkstra, 2000). The most advanced form of traffic calming—the "woonerf", "home zone", or "Spielstrasse"—imposes even more restrictions, requiring cars to travel at walking speed (officially set at 7km/hr in Germany). Pedestrians, cyclists, and playing children have as much right to use such residential streets as

motor vehicles; indeed, motor vehicles are required to yield to non-motorized users. In the Netherlands, Denmark, and Germany, traffic calming is area-wide and not for isolated streets. That ensures that faster through-traffic gets displaced to arterial routes designed to handle it and not simply shifted from one local road to another.

The most important safety impact of traffic calming is the reduced speeds of motor vehicles. That is crucial not only to the motorist's ability to avoid hitting pedestrians and bicyclists but also to the survival of non-motorists in a crash. The World Health Organization, for example, finds that the risk of pedestrian death in crashes rises from 5% at 20mph to 45% at 30mph and 85% at 40mph (WHO, 2008b).

Area-wide traffic calming in Dutch neighborhoods has reduced traffic accidents by 20% to 70% (Kraay and Dijkstra, 1989). Traffic calming in German neighborhoods has reduced traffic injuries overall by 20% to 70% and serious traffic injuries by 35% to 56% (Hass-Klau, 1990, 1993). A comprehensive review of traffic calming impacts in Denmark, Great Britain, Germany, and the Netherlands found that traffic injuries fell by an average of 53% in traffic-calmed neighborhoods (Preston, 1995). The benefits tend to be greatest for pedestrians, but serious cyclist injuries also fall sharply. Moreover, most studies find that traffic calming increases overall levels of walking and cycling (Herrstedt, 1992; Morrison et al., 2004; Transport for London, 2003; Webster and Mackie, 1996).

[Figure 11]

Integration with Public Transport

Coordinating walking and cycling with public transport enhances the benefits of all three modes, encouraging more walking and cycling as well as more public transport use (Brons et al., 2009; Givoni and Rietveld, 2007; Hegger, 2007; Martens, 2004 and 2007; Pucher and Buehler,

2009; TRB, 2005; U.S. DOT, 1998). Walking and public transport are especially complementary. In most countries, public transport trips usually start and end with walks to and from bus or rail stops. Even in the car-oriented USA, 90% of all public transport trips begin or end with a walk trip (USDOT, 2010). In Germany, walking accounts for about 70% of access to public transport stops, and cycling for another 10% (BMVBS, 2010). Thus, it is crucial to design public transport stations with safe, convenient, and comfortable pedestrian and cycling facilities, both in the stations themselves and on routes leading to the stops.

Bicycling supports public transport by extending the catchment area of transit stops far beyond walking range and at much lower cost than neighborhood feeder buses and park-and-ride facilities for cars. Conversely, access to public transport helps cyclists make longer trips than possible by bike alone. Public transport services also provide convenient alternatives when cyclists encounter bad weather, difficult topography, gaps in the bikeway network, and mechanical failures.

Compact Development with Mixing of Residential and Commercial uses

As noted earlier, trip distance can have an important impact on levels of walking and cycling. Most walking trips are 1km or shorter, and most bike trips are 3km or shorter. Land use is crucial for walking and cycling because it largely determines average trip distances. By promoting or even requiring compact, mixed-use development and discouraging low-density sprawl, land use policies in the Netherlands, Denmark, and Germany establish the ideal long-term framework for walkable and bikeable communities (Alterman, 2001; Buehler et al., 2009; Schmidt and Buehler, 2007; Nivola, 1999; TRB, 2001).

Over the past two decades, many German cities have been revising their land-use and transport plans to strengthen local neighborhood commercial and service centers (Buehler and

Pucher, 2010). The increased focus on sustainable development specifically encourages more variety in land uses in local neighborhoods by mixing housing with stores, restaurants, offices, schools, services, and other non-residential land uses. In many cities, land-use plans identify specific priority locations for small retail businesses in neighborhood centers. The plans specifically favor the establishment and strengthening of local neighborhood centers over peripheral development on the suburban fringe. Indeed, suburban shopping malls and big box retailers have been banned in some parts of Germany and the Netherlands because they promote sprawl, generate more car use, and put local stores out of business. The stated goal of current land use plans in many German cities is to keep trip distances short and to assure local accessibility by foot and bicycle.

In the USA, by comparison, the growing separation of residential from commercial land uses increases trip distances and makes the car a necessity (Ewing, 1997). Massive suburban shopping centers and strip malls have put central city retailers out of business and left many American cities without any department stores or major retailers. Surrounded by massive parking lots, suburban shopping centers are almost impossible to reach by foot or bike. Cul-de-sacs in suburban housing developments further discourage walking and cycling by making trips circuitous and excessively long. Instead of a dense network of short blocks typical in a grid pattern of streets, many suburban roads have few intersections and feed directly into high-speed traffic arterials, increasing the danger of any trips outside the neighborhood. The lack of sidewalks in most American suburbs further exacerbates the problem.

To encourage walking and cycling, it is necessary to provide a mix of land-uses and short trip distances, but people-friendly urban design is also needed to create a safe, convenient, and attractive environment that encourages cycling and walking.

Urban Design Oriented to People and Not Cars

The landscaping and architectural design of plazas, sidewalks, storefronts, and ground floor entrances to buildings can make walking a more interesting and pleasant experience and thus encourage more walking (Duany et al. 2009; Ewing, 1999; Nelessen, 1994; Van der Ryn and Calthorpe, 2008). Thus, many European cities specifically employ people-friendly urban design to attract more people into their centers (Gehl et al. 2001; Newman and Kenworthy, 1999). Wide sidewalks and pedestrian plazas can greatly encourage walking if they are well maintained and include attractive paving, comfortable benches, shade trees, outdoor cafes, public art, fountains, and street musicians. Short city blocks, pedestrian passageways within longer blocks, narrow streets, mid-block crosswalks, and median refuge islands facilitate pedestrian access and safety. Pedestrian-scale signage and lighting is also necessary. Many European city centers have employed these sorts of urban design measures to enhance their livability as well as to attract customers and visitors who stimulate the local economy (Newman and Kenworthy, 1999; Gehl and Gemzøe, 1996). Promoting walking might not be the main intent of such urban design improvements, but it is an important result nevertheless.

Some European countries have been at the vanguard of improvements in urban design in the suburbs as well. For example, many new suburban developments in the Netherlands, Denmark, and Germany have been specifically designed to provide safe and convenient pedestrian and cycling access (Buehler and Pucher, 2010; Netherlands Ministry of Transport, 2006; Pucher and Dijkstra, 2000). Residential developments almost always include other uses such as cultural centers, shopping, and service establishments that can easily be reached by foot or bike. Perhaps most important, suburbs in Europe almost always come with sidewalks for pedestrians and often include bikeways or bike lanes for cyclists. Parking lots in Dutch, Danish,

and German suburbs are generally built behind buildings, thus permitting easy storefront access to pedestrians and bicyclists. Some new developments even restrict car parking to the fringes of residential neighborhoods and shopping areas in order to minimize motorized traffic conflicts with pedestrians and cyclists.

Traffic Education

Driver training for motorists in the Netherlands and Germany is far more rigorous than in the USA (BMVBS, 2002, 2006; German Traffic Safety Council, 2001; Kultusministerium, 1995; Netherlands Ministry of Transport, 2006). A crucial aspect of that training in the Netherlands and Germany is the need to pay special attention to avoiding collisions with pedestrians and cyclists. Motorists are required by law to drive in a way that minimizes the risk of injury for pedestrians and cyclists even if they are jaywalking, cycling in the wrong direction, ignoring traffic signals, or otherwise behaving contrary to traffic regulations—especially if cyclists and pedestrians are elderly or children.

Traffic education of children has high priority in both The Netherlands and Germany (Pucher and Dijkstra, 2000). By the age of 10, most school children have received extensive instruction on safe walking and cycling practices. They are taught not just the traffic regulations but how to walk and bicycle defensively, to anticipate dangerous situations, and to react appropriately.

Traffic Regulations and Enforcement

Traffic regulations in the Netherlands, Denmark, and Germany strongly favor pedestrians and bicyclists (BMVBS, 2002, 2006; Fedtke, 2003; Fietsberaad, 2010; Netherlands Ministry of Transport, 2006; Pucher and Dijkstra, 2000). Even in cases where an accident results from illegal moves by pedestrians or cyclists, the motorist is almost always found to be at least partly

at fault. When the accident involves children or the elderly, the motorist is usually found to be entirely at fault. In almost every case, the police and the courts find that motorists should anticipate unsafe and illegal walking and cycling.

In addition, Dutch, Danish, and German police are far stricter in ticketing motorists, pedestrians, and cyclists who violate traffic regulations. Thus, walking against the light is not allowed in any German city and can easily result in a ticket and fine. Likewise, cyclists caught riding in the wrong direction, running red lights, making illegal turns, or riding at night without functioning lights can expect at least a warning notice and possibly a ticket and fine.

The most significant contrast with the USA is the much stricter enforcement of traffic regulations for motorists in Germany and the Netherlands. Penalties can be high even for minor violations. Not stopping for pedestrians at crosswalks is considered a serious offense and motorists can get ticketed for non-compliance, even if pedestrians are only waiting at the curb and not actually in the crosswalk. Similarly, red traffic signals are strictly enforced, and some intersections in German and Dutch cities have cameras that automatically photograph cars running red lights and stop signs. Finally, the punishment for traffic violations by motorists is far more severe in the Netherlands, Denmark, and Germany than in the USA.

Traffic violations in Europe can lead to large fines as well as suspension of the driver's license. In Germany, for example, speeding in urban areas incurs fines of 80 – 760 Euros, depending on the specific location and the degree of excess speed. Driving more than 30km/h above the speed limit results in a large fine and suspension of the driver's license for a minimum of one month. Other violations result in fines and penalty points on the driver's official record, which are registered in a federal traffic police database. If drivers accrue too many penalty points over time, the license is suspended (BMVBS, 2009).

Complementary Roadway, Parking, and Taxation Policies

Most of the above policies refer to measures that make walking and cycling safer and more convenient in Europe. Many other important government policies encourage walking and cycling indirectly. For example, the provision of road capacity and parking facilities is far less generous than in American cities (Buehler, 2009; Newman and Kenworthy, 1999; TRB, 2001). Indeed, roadway and parking supply has been deliberately reduced in many Dutch, Danish, and German cities over the past few decades in order to discourage car use in the city center (Fietsberaad, 2006, 2010). The many restrictions on car use and parking reduce the relative speed, convenience, and flexibility of car travel compared to walking and cycling (Rietveld and Daniel, 2004).

Dutch, Danish, and German cities restrict auto use not only through traffic calming, auto-free zones, and dedicated rights of way for pedestrians and cyclists (Buehler et al., 2009; Newman and Kenworthy, 1999; Pucher and Dijkstra, 2000; TRB, 2001). They also enforce lower general speed limits for motor vehicles in cities—usually 50 km per hour (31 mph). Parking is much more limited and more expensive than in American cities. In addition, most Dutch, Danish, and German cities prohibit truck traffic and through-traffic in residential neighborhoods. Motor vehicle turn restrictions are widespread in northern Europe, and right turns on red are illegal, while they are now permitted in all American states. Several studies have shown that the introduction of right turn on red in the USA in the mid- to late-1970s greatly increased pedestrian and cyclist injuries (Preusser et al., 1982; Zador et al., 1982). In spite of strong evidence of the dangers they pose for pedestrians and cyclists, right turns on red continue to be allowed in the USA because they speed up car travel.

Moreover, sales taxes on petrol and new car purchases, import tariffs, registration fees, license fees, driver training fees, and parking fees are generally much higher in Europe than in

the USA (Buehler et al., 2009; EUROSTAT, 2005-2007; Nivola, 1999; Pucher, 1995a, b; TRB, 2001). That results in overall costs of car ownership and use two to three times higher in Europe. That higher cost discourages car use to some extent and thus promotes alternative ways of getting around, including walking and cycling, which are much cheaper than the car.

Climate, Topography, Culture, and Other Factors

Climate, topography, history, and culture also influence cycling and walking levels. Most of these factors are beyond the control of policy makers and planners, however, and are not the focus of this paper. Climate and topography obviously influence walking and cycling. Rain, snow, ice, and wind as well as extreme heat and cold can make walking and cycling unpleasant and even unsafe (Heinen et al. 2010). Such weather conditions do not necessary prevent walking and cycling, however. For example, the Netherlands, Denmark, northern Germany, and the Pacific Northwest of North America have high rates of cycling in spite of their rainy climates. Similarly, cities such as Helsinki, Stockholm, Montreal, Ottawa, and Minneapolis have high cycling rates in spite of their very harsh winters. Cycling rates are generally higher where the topography is flat, such as in the Netherlands, Denmark, and northern Germany. There are exceptions, however, such as the high cycling levels in Switzerland and Austria and the cities of San Francisco and Seattle, among the hilliest and most bike-oriented of American cities. The evidence on the impact of topography is mixed. Some studies show lower levels of active transport in hilly terrain, while others find no effect (Heinen et al. 2010).

Culture and habit tend to foster cycling in cities and countries with high levels of cycling but deter cycling—especially among non-cyclists—where cycling levels are low and where it is viewed as a fringe mode (de Bruijn, 2009; Gatersleben and Appleton, 2009; Pucher et al. 1999). Nevertheless, culture and habits can change over time. Some cities in the traditionally car-

oriented and sprawling USA have successfully promoted cycling by the same sorts of measures used in Dutch, German, and Danish cities: improving cycling infrastructure, traffic calming neighborhoods, integration with public transport, bike sharing, and training and education programs. For example, Portland (Oregon) and Minneapolis (Minnesota) raised cycling levels more than five-fold from 1990 to 2008 (Bike Walk Twin Cities, 2008; City of Portland 2010). New York City, San Francisco, and Washington more than tripled cycling since 1990 (Pucher et al, 2010). Thus, history and culture need not be insuperable obstacles to increasing walking and cycling, just as they do not guarantee continued high levels of walking and cycling, as shown by the sharp declines in active travel in France and the UK. As argued in this paper, policies appear to be far more important than history and culture in explaining walking and cycling trends.

Conclusions

Walking and cycling are healthy ways to get around. These forms of active travel contribute to daily physical activity, aerobic fitness, and cardiovascular health while helping to protect against obesity, diabetes, and various other diseases. The mounting evidence on the health benefits of walking and cycling has led many government agencies, public health organizations, and medical journals to advocate more walking and cycling to improve individual health and to reduce air pollution, carbon emissions, congestion, noise, traffic dangers, and other harmful impacts of car use. In short, there is consensus on the need to increase daily walking and cycling levels to promote public health.

As discussed in this paper, there are many ways to encourage more walking and cycling while also making them safer: improved infrastructure (such as sidewalks, crosswalks, cycle tracks, and bike parking); car-free city centers and traffic calming of residential neighborhoods; integration with public transport; training and education programs; compact, mixed-use

development; good urban design; and various measures restricting car use. Countries and cities with high levels of walking and cycling as well as good safety records tend to have good walking and cycling infrastructure as well as many other supporting policies and programs, while those with low walking and cycling rates and poor safety records generally have done much less.

The infrastructure, programs, and policies needed to increase walking and cycling are well known and tested, with decades of successful experience in many European cities. One key lesson is that no single strategy is sufficient. As shown by a recent international review of the literature, communities must implement a fully integrated package of measures such as those discussed previously in this paper (Pucher et al., 2010). A comprehensive approach has much greater impact on walking and cycling levels than individual measures that are not coordinated. The impact of any particular measure is enhanced by the synergies with complementary measures in the same package.

Explaining the societal-wide benefits of walking and cycling is crucial for generating the public and political support needed to implement the necessary policies. One important benefit of improved walking and cycling conditions is the reduced risk of death and injury. Public campaigns should emphasize the direct impacts of traffic safety on individuals, their families, and their friends. Such an appeal should perhaps focus on the safety needs of children and seniors, who are most vulnerable and deserve special consideration. Improved safety is a goal in itself, but it would also encourage more people to walk and cycle on a regular basis, providing them with valuable exercise, mobility options, independence, and even fun.

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Figure 11. In response to citizen demand most German cities have traffic calmed their residential neighborhoods with maximum speed limits of 30km/h. Similar to the Dutch concept of 'woonerf,' many German cities have also introduced a more advanced form of traffic calming that turns neighborhood streets to home zones ("Spielstrassen")—where the speed limit is 7km/h and cars are required by law to yield to cyclists, pedestrians, and children at play. The combination of low traffic speeds and traffic calming design measures provides a safe and attractive environment for cyclists and pedestrians without any special bicycle infrastructure or even sidewalks.

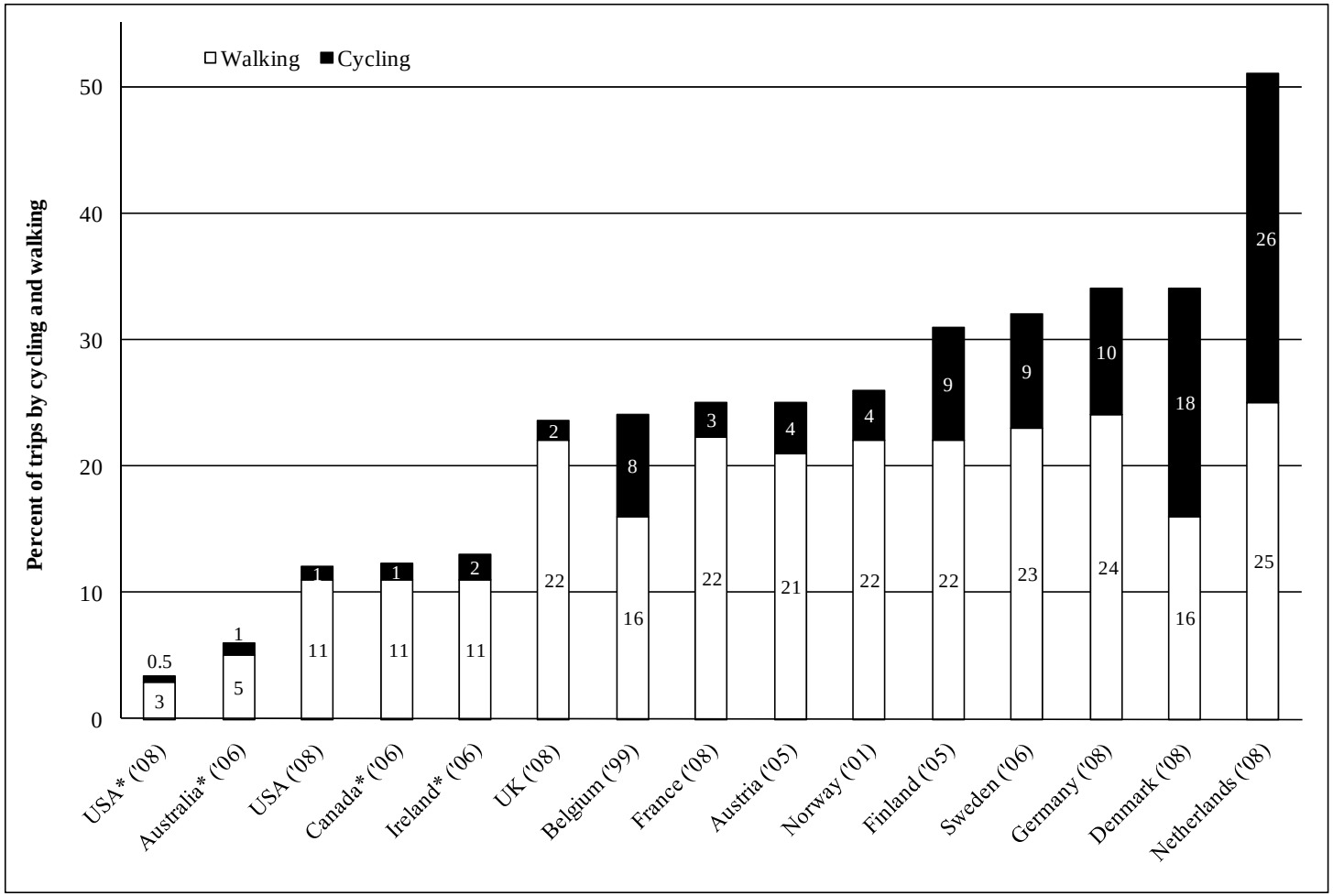

Figure 1. Cycling and walking share of daily trips in Europe, North America, and Australia, 1999-2008
Note: The latest available travel surveys were used for each country, with the survey year noted in parentheses after each country name. The modal shares shown in the figure reflect travel for all trip purposes except for those countries marked with an asterisk, which only report journeys to work derived from their censuses. Dissimilarities in data collection methods, timing, and variable definitions across countries and over time limit the comparability of the modal shares shown in the figure.
Sources: Bassett et al. (2008); BMVBS (2010); Danish Ministry of Transport (2010); Department for Transport (2010); Pucher and Buehler (2008a); Statistics Netherlands (2010); USDOC (2009); USDOT (2010).

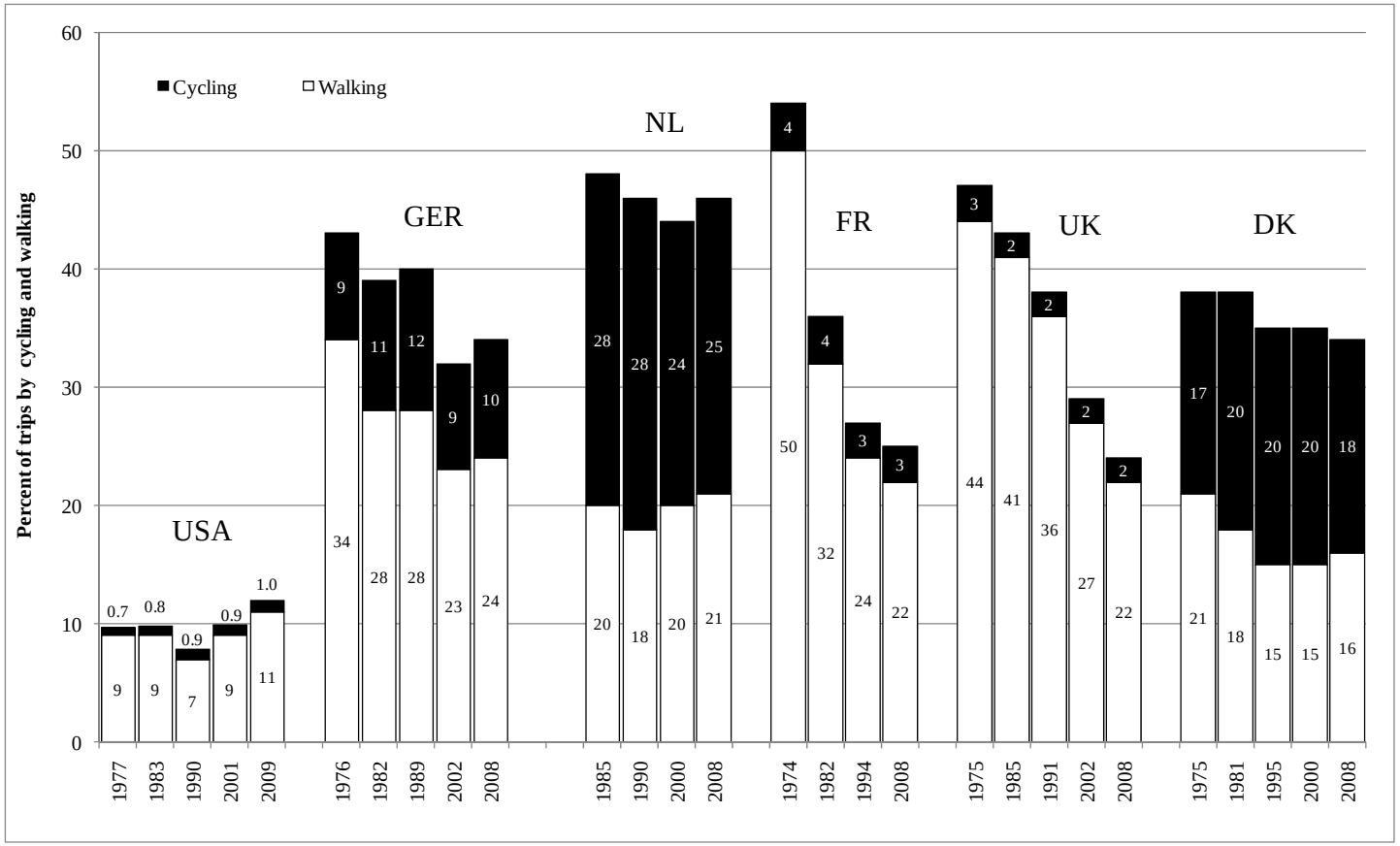

Figure 2. Trend in combined cycling and walking share of all daily trips in the USA, Germany, the Netherlands, France, the UK, and Denmark, 1974-2009

Notes: Dissimilarities in data collection methods, timing, and variable definitions across countries and over time limit the comparability of the modal shares shown in the figure. The increase reported for the USA in the combined walk and bike share of trips between 1995 and 2001 was probably due to a change in methodology that captured previously under-reported walk trips. For detailed explanations of each survey see Kunert et al. (2002) and Bassett et al. (2008).

Sources: BMVBS (2010, 2004); Danish Ministry of Transport (2010); Department for Transport (2010, 2004); USDOT (2010); ORNL (2004); Papon (2001); SOeS (2010); SWOV (2010).

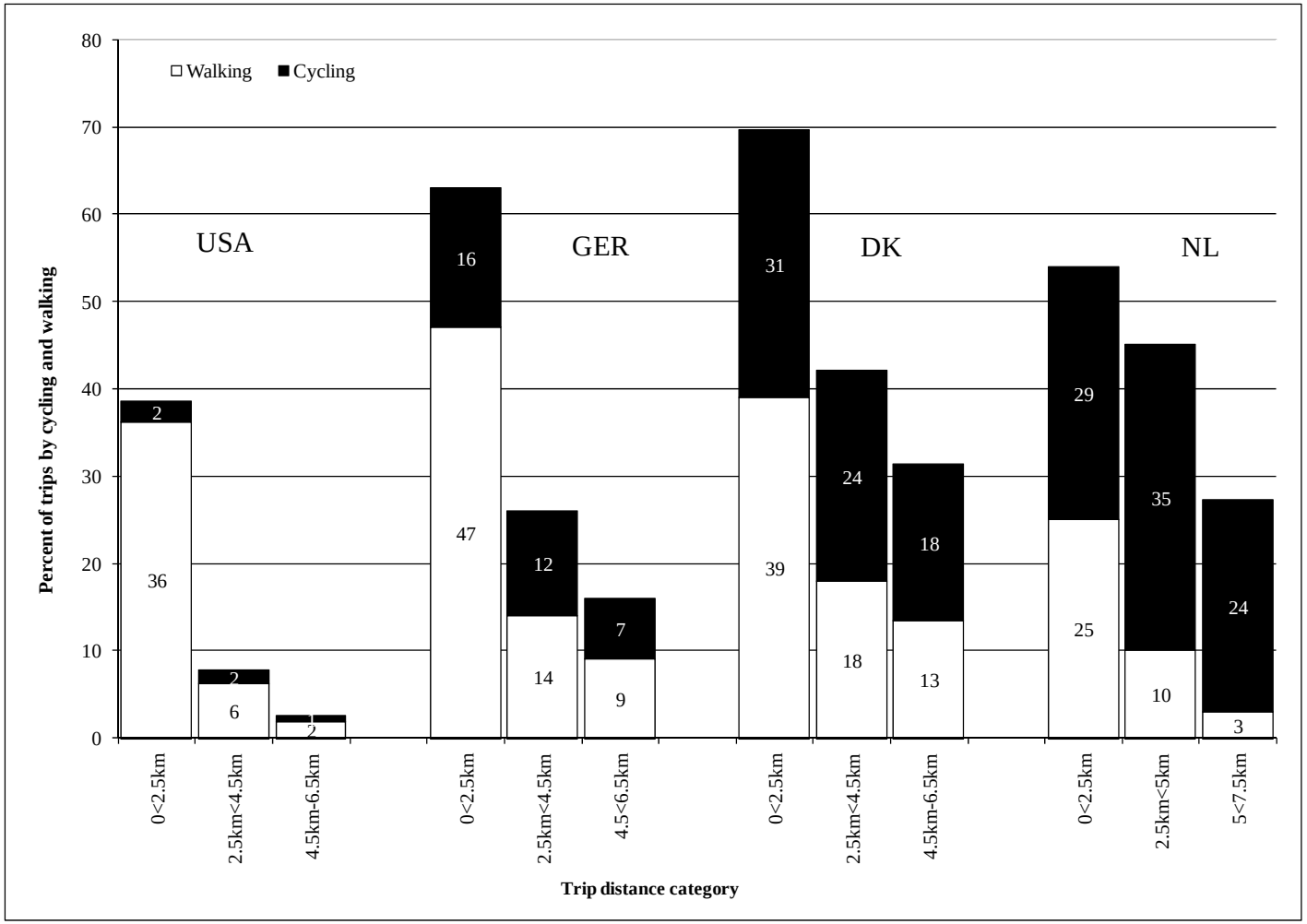

Figure 3. Cycling and walking share of trips within each trip distance category in the Netherlands, Denmark, Germany, and the USA, 2008 (Percent of trips by all modes for all purposes)

Note: Trip distance categories for the Dutch survey differ somewhat compared to those used in the other countries. For all countries the percentages shown refer to the cycling and walking share of all trips within each particular trip distance category.

Sources: BMVBS (2004); Danish Ministry of Transport (2010); Pucher and Buehler (2008a); Statistics Netherlands (2010); USDOT (2010)

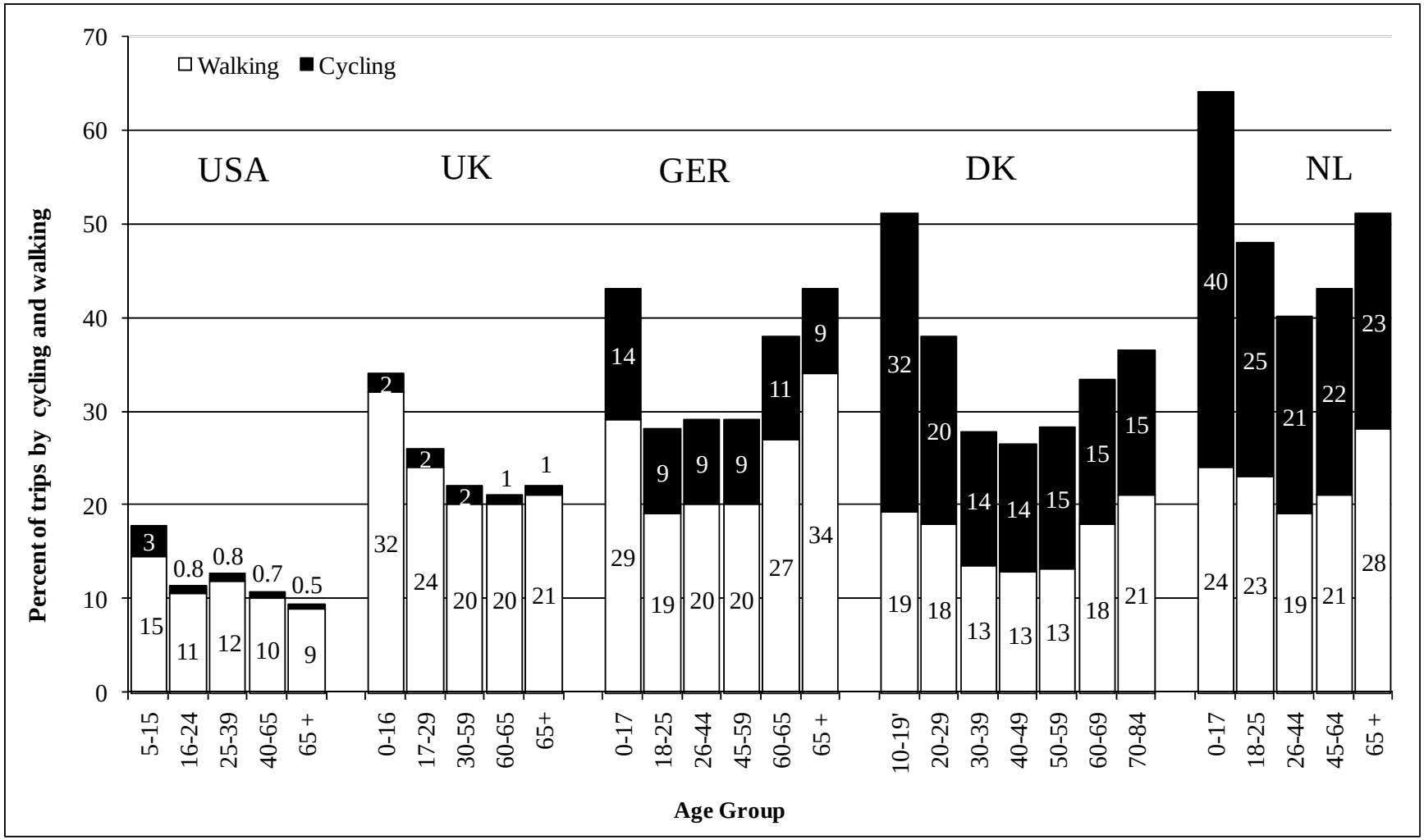

Figure 4. Cycling and walking share of trips within each age group in the Netherlands, Denmark, Germany, the UK, and the USA, 2008 (As percent of trips by all modes for all trip purposes)

Note: Each country uses somewhat different age categories in their travel surveys. The percentages shown in the figure refer to the walking and cycling share of all trips made by persons within each age category.

Sources: BMVBS (2010); Danish Ministry of Transport (2010); Department for Transport (2010); Pucher and Buehler (2008a); Statistics Netherlands (2010); USDOT (2010).

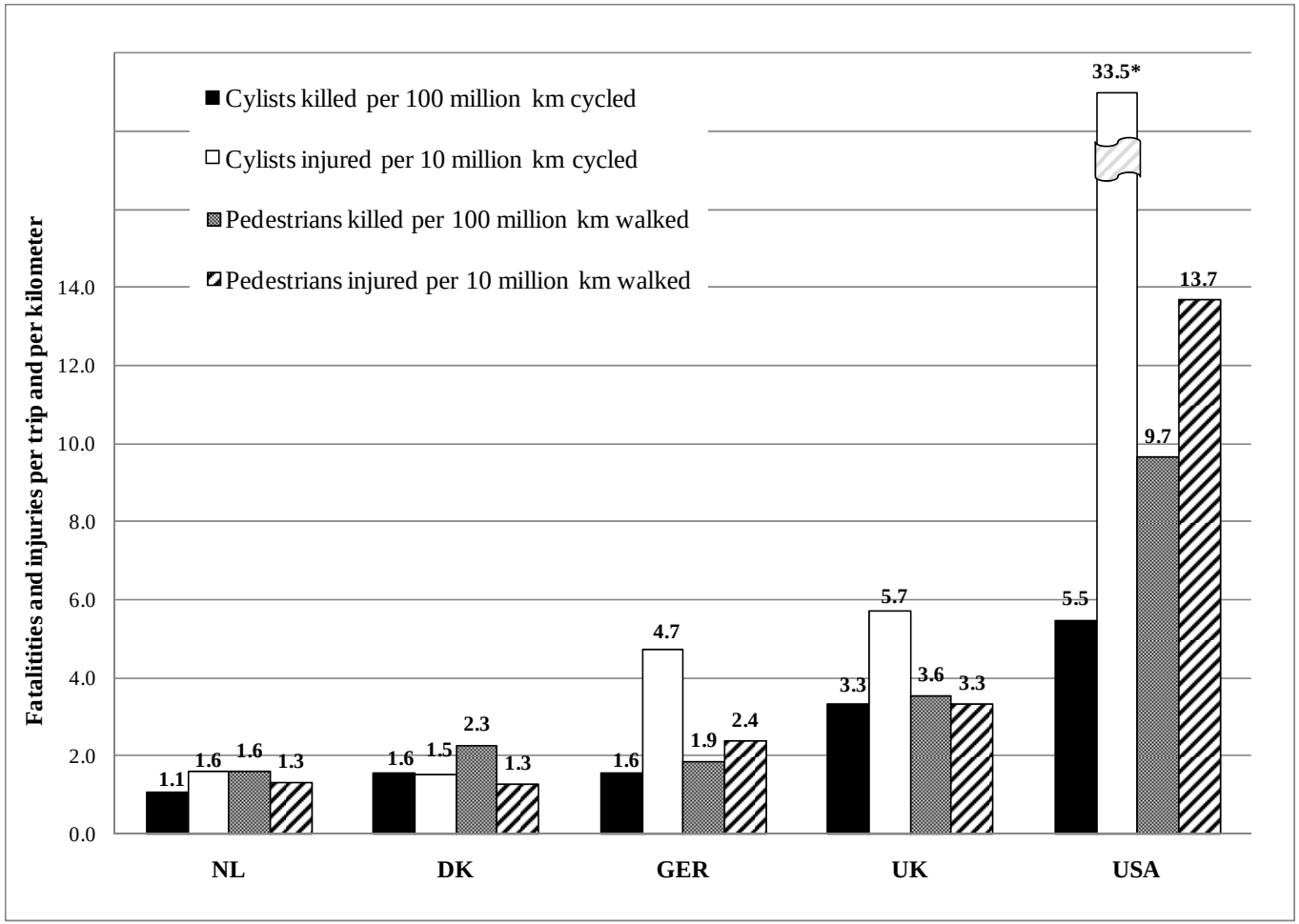

Figure 5. Cyclist and pedestrian fatality rates and non-fatal injury rates in the Netherlands, Denmark, Germany, the UK, and the USA, 2004-2008

Note: To control for annual fluctuations a five year average (2004-2008) was used for pedestrian and cyclist injuries and fatalities. Trips and kilometers for cycling and walking exposure levels were derived from 2008 travel survey data.

* Cyclist injury rate for the USA is off the chart; thus, it is shown here with a discontinuous bar.

Sources: BMVBS (2010); Danish Ministry of Transport (2010); Department for Transport (2010); Pucher and Buehler (2008a); Statistics Netherlands (2010); USDOT (2010).

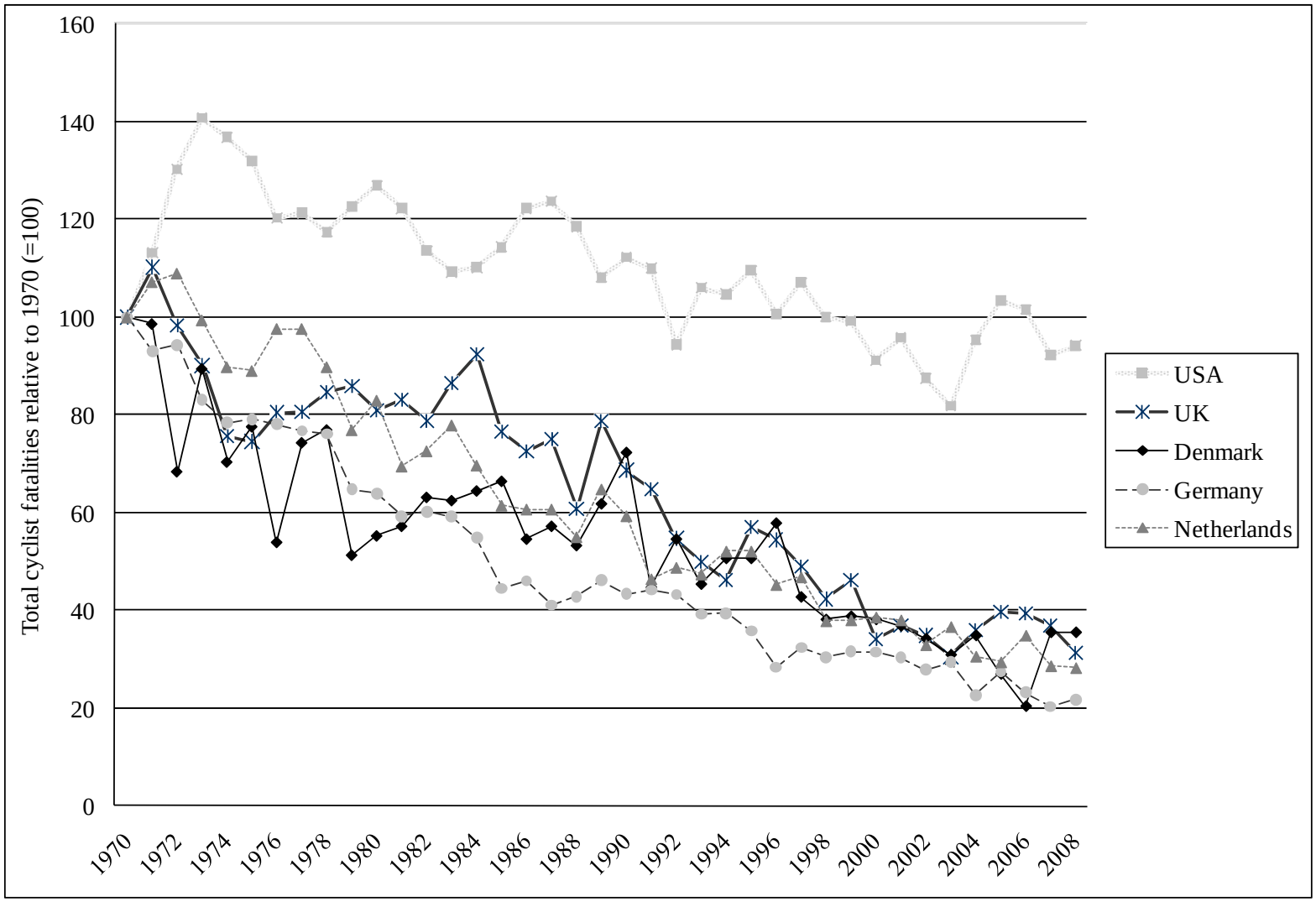

Figure 6. Trend in cycling fatalities in the Netherlands, Denmark, Germany, the United Kingdom and the USA, 1970 - 2008 (Percent relative to 1970 level)

Sources: IRTAD (2010); Pucher and Dijkstra (2000).

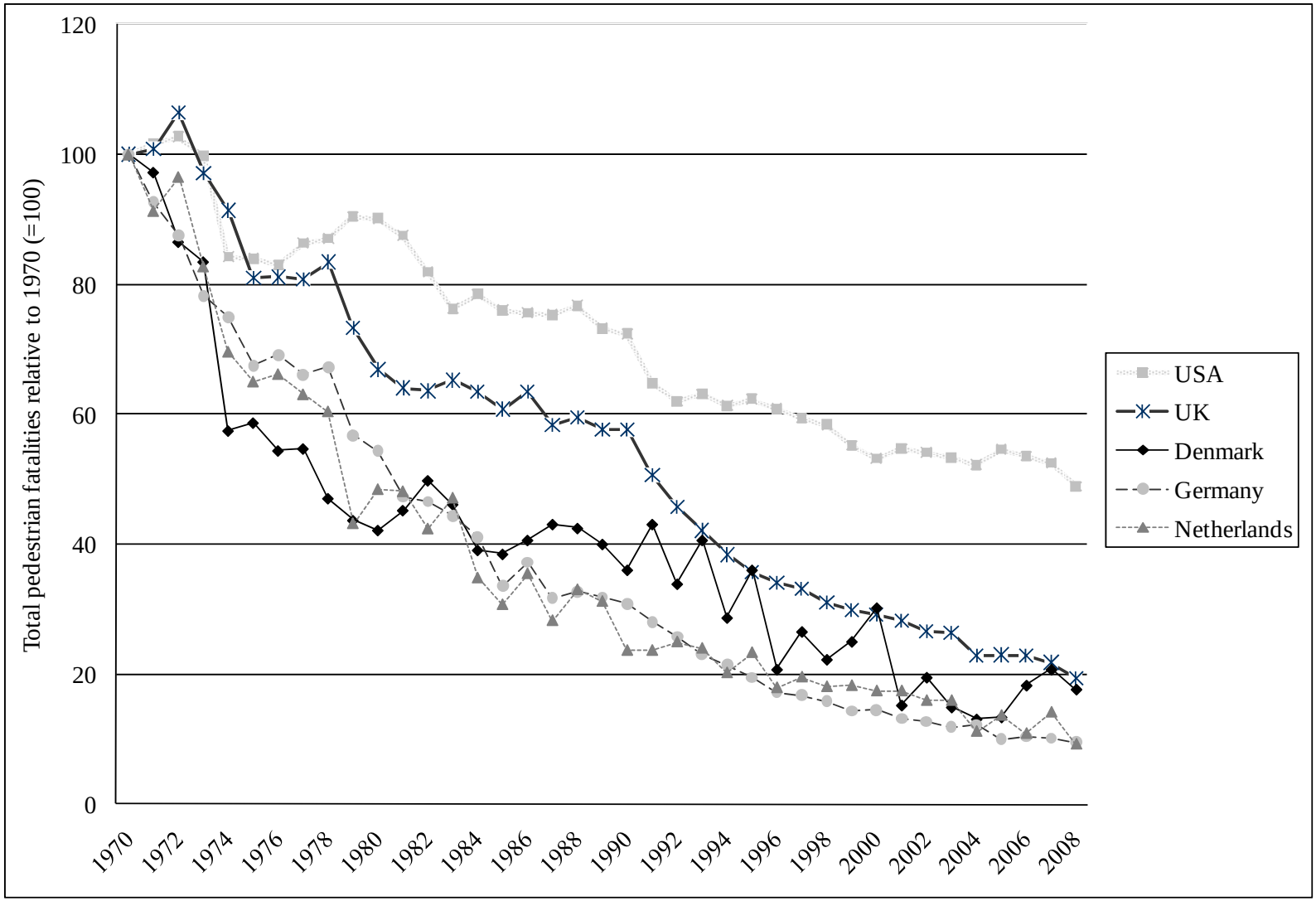

Figure 7. Trend in pedestrian fatalities in the Netherlands, Denmark, Germany, the United Kingdom and the USA, 1970 - 2008 (Percent relative to 1970 level)
Sources: IRTAD (2010); Pucher and Dijkstra (2000).

Figure 8. Since the early 1970s an increasing number of German cities have banned automobiles from the city center. Today most German cities have a car-free pedestrian zone that provides a safe, lively, and attractive environment for leisure and shopping. Often the walking experience is enhanced by cobblestone pavement, pedestrian scale lighting, fountains, tree shaded squares, outdoor cafes, shops, street musicians, and farmers markets.
Photo credit: Ralph Buehler

Figure 9. The City of Copenhagen, Denmark provides an extensive network of traffic-protected cycle tracks, separated from motor vehicles by a raised curb. At intersections the bicycle paths are clearly marked with blue pavement coloring to alert motorists that they must yield to cyclists. Such separate facilities help explain why 55% of bike trips in Denmark are by women. The cycle track shown above serves over 55,000 bike trips per day.
Photo credit: Susan Handy

Figure 10. Over the last decade, many American cities have begun planning for cycling. Here in Santa Barbara, California, for example, motor vehicle lanes were replaced by a bi-directional bike path with a palm tree shaded median to protect cyclists from car traffic and the sun. Note also the well marked pedestrian crossing and the separate pedestrian walkway to the right. *Photo credit*: Ralph Fertig

Figure 11. In response to citizen demand most German cities have traffic calmed their residential neighborhoods with maximum speed limits of 30km/h. Similar to the Dutch concept of 'woonerf,' many German cities have also introduced a more advanced form of traffic calming that turns neighborhood streets to home zones ("Spielstrassen")—where the speed limit is 7km/h and cars are required by law to yield to cyclists, pedestrians, and children at play. The combination of low traffic speeds and traffic calming design measures provides a safe and attractive environment for cyclists and pedestrians without any special bicycle infrastructure or even sidewalks.
Photo credit: Peter Berkeley

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