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Reducing car dependence in the heart of Europe: lessons from Germany, Austria, and Switzerland

Ralph Buehler[a], John Pucher[b], Regine Gerike[c] and Thomas Götschi[d]

[a]Urban Affairs and Planning, School of Public and International Affairs, Virginia Tech, Alexandria Center, Alexandria, VA, USA; [b]Bloustein School of Planning and Public Policy, Rutgers University, New Brunswick, NJ, USA; [c]Institute of Transport Planning and Road Traffic, Technische Universität Dresden, Dresden, Germany; [d]Epidemiology, Biostatistics, and Prevention Institute, University of Zurich, Zurich, Switzerland

ABSTRACT

Munich, Berlin, Hamburg, Vienna, and Zurich – the largest cities in Germany, Austria, and Switzerland – have significantly reduced the car share of trips over the past 25 years in spite of high motorisation rates. The key to their success has been a coordinated package of mutually reinforcing transport and land-use policies that have made car use slower, less convenient, and more costly, while increasing the safety, convenience, and feasibility of walking, cycling, and public transport. The mix of policies implemented in each city has been somewhat different. The German cities have done far more to promote cycling, while Zurich and Vienna offer more public transport service per capita at lower fares. All five of the cities have implemented roughly the same policies to promote walking, foster compact mixed-use development, and discourage car use. Of the car-restrictive policies, parking management has been by far the most important. The five case study cities demonstrate that it is possible to reduce car dependence even in affluent societies with high levels of car ownership and high expectations for quality of travel.

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Introduction

Car ownership and use have been increasing over the past few decades in most of the world's countries. The rate of growth in car ownership and use has been especially fast in the developing world (Dimitrou & Gakenheimer, 2011; UN Habitat, 2013). Recent studies, however, suggest a stagnation or even decline in car ownership, use, and driver licencing rates in some of the highest-income countries. Millard-Ball and Schipper (2011) examined annual national data from 1970 to 2008 for the USA, Canada, Australia, France, the UK, Sweden, Germany, and Japan. Controlling for income levels, they found steady increases in car ownership and use per capita until about 2000, but a levelling off or decline since 2000. Kuhnimhof et al. (2012) compared car ownership and driver licencing rates across generations in Germany, France, Great Britain, Japan, Norway, and the USA, finding that for the first time, the younger generation is driving less than previous

CONTACT Ralph Buehler ralphbu@vt.edu Urban Affairs and Planning, School of Public and International Affairs, Virginia Tech, Alexandria Center, 1021 Prince Street, Suite 200, Alexandria, VA 22314, USA

generations and using public transport, walking, and cycling more. In 2013 Transport Reviews published an entire issue examining the topic of peaking of car ownership and use. Most of the articles confirmed the recent levelling off or much slower growth in car ownership and use in Western countries (Goodwin & van Dender, 2013).

Data on travel mode choice for some specific high-income cities reveal a decrease in the share of trips by car and an increase in the mode share of walking, bicycling, and public transport over the past two decades. Perhaps the most famous examples are Singapore, Hong Kong, Seoul, London, Paris, Copenhagen, and Stockholm (Cervero, 1998; Newman & Kenworthy, 2015; UN Habitat, 2013). Even in the USA, the two most recent national travel surveys report a fall in car mode share of daily trips (all trip purposes) from 86% in 2001 to 83% in 2009 (USDOT, 2010). The US Census reports a decline in the car share of work commuters from 88% in 2000 to 86% in 2014 (US Census Bureau, 2000–2015). For some American cities, however, the reduction from 2000 to 2014 was much larger: 76–67% in Portland, Oregon; 73–68% in Minneapolis, Minnesota; 49–41% in Washington, DC; 33–27% in New York City.

Although their cities have not attracted as much worldwide media attention, Germany, Switzerland, and Austria have been at the forefront of promoting walking, cycling, and public transport through a range of innovative programmes – both at the national and local level – while discouraging car use, especially in city centres and residential neighbourhoods. Many of the key programmes to improve alternatives to the car were introduced, or first widely implemented, in these three countries. Moreover, the countries are important because they are home to almost 100 million residents and constitute an important core of Europe's economy.

This article focuses on five cities: Zurich and Vienna, the largest cities in Switzerland and Austria, and Berlin, Hamburg, and Munich, the three largest cities in Germany. The article examines travel trends since 1990 in each of the cities to determine to what extent they have, in fact, achieved their goal of reducing car dependence. It then describes the range of policies the cities have implemented to create a more balanced transport system, including the car but providing safe, convenient, and inexpensive walking, cycling, and public transport alternatives, and thus increasing travel choices. The objective is to identify similarities and differences among the cities in transport policies they have implemented and to offer the experience of these five cities for consideration by other cities seeking to reduce car use.

As shown in Figure 1, car ownership per 1000 inhabitants has roughly doubled since 1970 in most North American and Western European countries, as well as in Australia and New Zealand. For all countries combined, the average annual rate of growth in car ownership per 1000 population was 3.9% from 1970 to 1980, 1.9% from 1980 to 1990, 1.3% from 1990 to 2000, and 0.9% from 2000 to 2012. Thus, the rate of increase in the most recent period is less than a fourth the rate in the earliest decade. Although Germany, Austria, and Switzerland are among the Western European countries with the highest rates of car ownership, their motorisation rates have also been levelling off in recent years, with much smaller average annual increases since 2000 (0.5%) than in the decades from 1970 to 1980 (5.5%), 1980–1990 (2.8%), 1990–2000 (1.4%).

Perhaps more importantly, the mode share for private cars in the three case study countries is less than 60% of daily trips, among the lowest of the countries shown in Figure 2. Walking, cycling, and public transport account for over 40% of all daily trips in

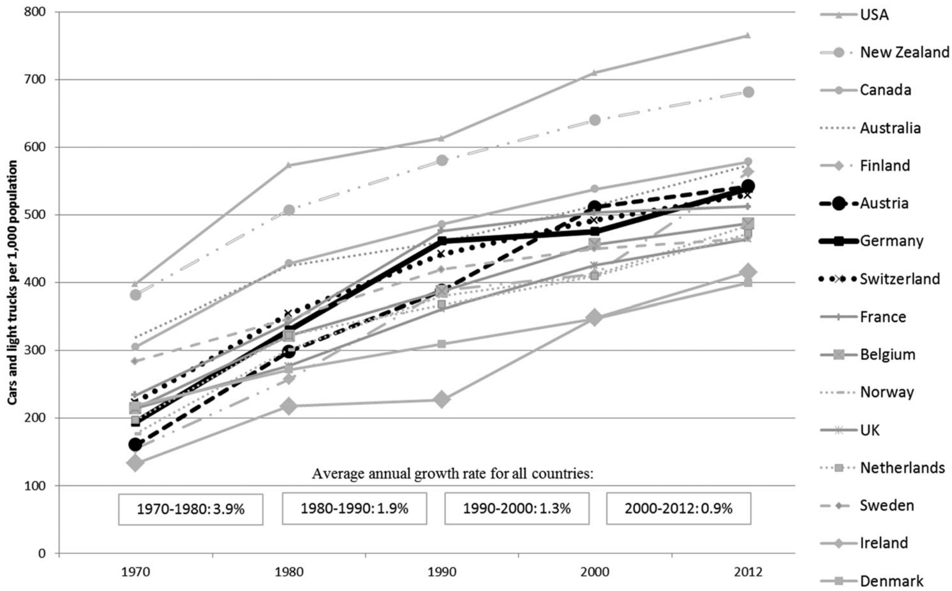

Figure 1. Trend in motorisation in OECD countries, 1970–2012 (cars and light trucks per 1000 population).
Sources: EUROSTAT (2005–2014) and OECD (2003–2015).

the three countries. The high levels of car ownership per 1000 population in Germany (539), Austria (542), and Switzerland (529) in 2012 did not deter their residents from making almost half of their trips by walking, cycling, and public transport. By comparison, levels of car ownership in 2012 were highest in the USA (765), and walking, cycling, and public transport together accounted for only 14% of all daily trips. The seeming incompatibility of high motorisation levels and high rates of walking, cycling, and public transport use, as suggested by the US example – and to a lesser extent by Australia, Canada, and New Zealand – does not apply to our three case study countries.

Overview of case study cities

Table 1 provides an overview of the demographics, socio-economics, and travel behaviour indicators in the five case study cities. The differences among the cities in their size and political boundaries of their cities vs. their metro areas can greatly affect transportation statistics. That is important for the analysis that follows, which focuses on the city and not the metropolitan area. As shown in this article, suburban residents have different travel behaviour than residents of the city.

In this article we use three terms to distinguish three portions of the metro area of special interest: "city centre" also called city core or inner city; "city" as defined by political boundaries; and the greater "metropolitan area", usually coinciding with the service area of the regional public transport association (Verkehrsverbund), which includes substantial amounts of suburban areas outside of the city limits.

Although the cities are the largest in their respective countries, they vary greatly in population. The metropolitan populations of the five cities vary in roughly the same

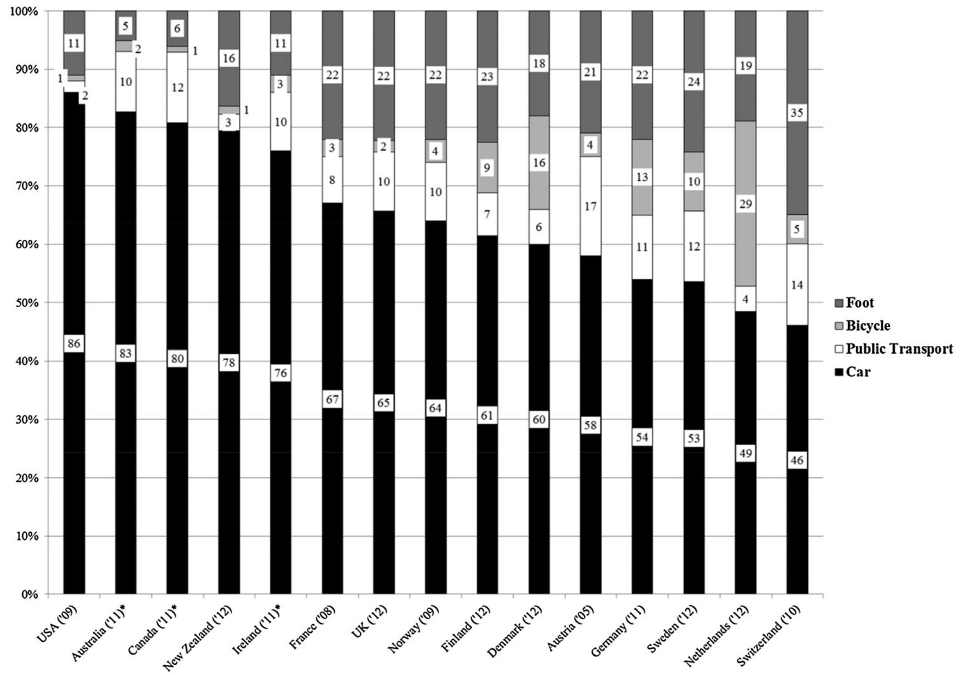

Figure 2. Percentage share of daily trips by car, public transport, bicycle, and foot in 15 OECD countries, 2009–2012.

Notes: Survey methods and data collection periods vary across countries. Data for Australia, Canada, and Ireland are for the commute to work only and marked with an asterisk (*). The Swiss travel survey captures a much higher share of very short trips than other surveys.

Sources: Data collected from national statistical offices of each country. All of the surveys are samples of populations and thus only approximations of actual travel behaviour. Most surveys only report the main mode of transport for a trip and not the short access trips by other modes. Small differences between countries should not be over-interpreted (BFS, 2011; CBS, 2014; DfT, 2014; DMT, 2014; HERRY, 2012; MOP, 2010; SIKA, 2014; SOeS, 2010; StatCan, 1996–2010; TOI, 2011; USDOT, 2010; WSP, 2014).

proportions, with about twice the population of the central city, except for Zurich, whose metropolitan population is three times larger than the city population.

The northern cities of Berlin (−3%) and Hamburg (+3%) have experienced stagnation in their populations since 1992 while Vienna (+14%), Munich (+10%), and Zurich (+9%) have grown by about a tenth. Vienna, Munich, Zurich, and Hamburg are all affluent cities. Calculated on the basis of purchasing power parities (adjusting for cost of living) instead of currency exchange rates, GDP per capita in 2012 (in US dollars) ranged from $56,666 in Zurich and $56,322 in Munich to $52,555 in Hamburg and $45,600 in Vienna. The exception is Berlin, with a much lower per-capita GDP of $36,259.

The variation in per-capita income is only partly reflected in motorisation levels in the five cities. Berlin has by far the lowest rate (324), which would correspond to its much lower per-capita income. Hamburg and Vienna have roughly the same per-capita GDP, but Hamburg's motorisation rate is much higher (474 vs. 395). One possible explanation is that Vienna's population density is almost twice as high as Hamburg's. Similarly, Munich and Zurich have roughly the same GDP per capita, but the motorisation rate in

Table 1. Demographic, economic, geographic, and daily travel characteristics of case study cities.

Statistical indicator	Unit of measure	Berlin	Hamburg	Munich	Vienna	Zurich
Population city (2012)	*Millions of residents*	3.4	1.7	1.4	1.8	0.4
Population metro region (2012)	*Millions of residents*	5.1	3.2	2.7	2.6	1.2
Population change city (%)	*1992–2012*	−3%	3%	10%	14%	9%
Average household size		1.7	1.8	1.8	2.0	1.8
GDP per capita (2012)	*Euros*	29,864	52,555	60,084	45,600	75,402
	US$ (using PPP)	36,259	49,757	56,322	48,546	56,666
Major industry sectors		Government; administration	Large port; media; publishing houses	Car/truck industry; IT; tourism; technology	Government; headquarters Austrian and Eastern EU companies	Banking; insurance
Land area city	*km^2*	892	755	311	415	88
Population density	*People per km^2 of total land area*	3800	2300	4500	4300	4200
Share of land area for transport infrastructure and settlements		0.7	0.6	0.8	0.5	0.8
Population density	*People per km^2 settlement and transport area*	5400	3900	6000	8500	6900
Households without a car	*%*	41	32	30	34	48
Households with only 1 car	*%*	46	53	55	50	42
Households with 2+ cars	*%*	13	15	15	16	10
Motorisation	*Cars and light trucks per 1000*	324	404	475	395	368
Number of trips per person per day		3.0	3.3	3.4	2.7	3.5
Average trip length (trips < 100 km)	*km*	6.7	6.7	7.0	6.7	6.2
Average trip length	*km*	6.9	7.8	10.0	n.a.	8.9
Public transport trips per capita per year (linked-passenger trips)	*Verkehrsverbund serivce area*	222	209	239	318	438

Note: Unless otherwise noted, information in the table refers to the city itself and not the surrounding area outside the political boundaries of the city.
Sources: City of Munich (2015c), City of Vienna (2014b), City of Zurich (1990–2014), HVV (1990–2013), MVV (1990–2013), Northern Germany Statistics (2014), Statistics Berlin-Brandenburg (2015), VBB (2000–2014), VOR (2012), and ZVV (2014).

Munich is much higher (550 vs. 368). As noted earlier, Zurich is an exception among the five metropolitan areas because its city boundaries only include a very small area (88 km^2), housing only one-third of total metro area population compared to more than half in the four other cities. In addition, Zurich has twice as high a share of students among its population (17% vs. 8% in Munich) (Randelhoff, 2013). As discussed later in this article, differences in transport policies also account for some of the variation in motorisation rates.

As documented in the extensive review by Ewing and Cervero (2010), many studies show that population density helps explain the variation in public transport use and motorisation rates among the cities. Population density per sq km of developed land (excluding parks, woods, lakes, and greenspace) is by far the highest in Vienna (8500) and Zurich (8900), the 2 cities with the highest rates of public transport use. Hamburg has the lowest density (2300) as well as the lowest rate of public transport usage of the 5 cities (209 trips per capita per year), less than half the rate in Zurich (438).

Trends in motorisation and travel behaviour in five cities

Motorisation rates in the five case study cities have trended similarly to their respective countries, with sharp increases from 1970 to 1990 and much smaller increases since 1990 (Figure 3). Motorisation rates would be expected to affect travel behaviour, as documented in the comprehensive reviews by Ingram and Liu (1999), Dargay and Gately (1999), and Buehler (2011). The relationship is only partially confirmed among our five cities.

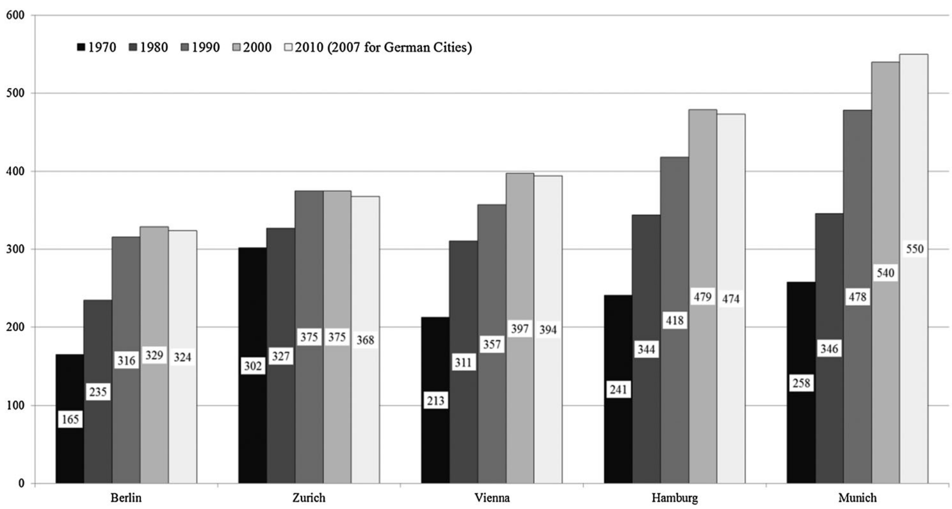

Figure 3. Trend in motorisation in Berlin, Zurich, Vienna, Hamburg, and Munich, 1970–2010 (cars and light trucks per 1000 population). Sources: City of Munich (2015c), City of Vienna (2014b), City of Zurich (1990–2014), Kalender (2012), Krause (2009), Northern Germany Statistics (2014), Pirhofer and Stimmer (2007), and Statistics Berlin-Brandenburg (2015).

Notes: 2010 data are available for the three German cities, but they are not comparable with previous years due to a 2008 Germany-wide change in methodology for reporting statistics on car ownership. Thus, the graphic above shows rates in 2007 which are comparable with data reported for the earlier years.

Munich has the highest motorisation rate, but its car mode share of trips is lower than Hamburg's, which has the highest car mode share of all five cities. Conversely, Berlin has the lowest motorisation rate, but its car mode share is higher than in Zurich and Vienna, which have higher motorisation rates. Nevertheless, the trend toward stable or falling motorisation rates (Figure 3) is consistent with the falling car mode share of trips, especially since about 2000 (Figure 4).

In Berlin, Munich and Zurich, there was a slight increase in the car share of trips from about 1990 until 2000, and then a decrease from 2000 to the most recent survey year (see Figure 4). Vienna and Hamburg have experienced a decline in the mode share of car use since about 1990. These travel surveys only report trips made by city residents, thus excluding suburban residents as well as visitors to the city. As noted in Figure 5, car use is considerably higher in the suburbs than shown here for city residents alone. Only approximate comparisons can be made among the five cities because the available travel surveys vary in methodology and timing. Except for Hamburg (42%), the car's mode share has fallen to less than a third of all daily trips: Vienna (27%), Zurich (30%), Berlin (30%), and Munich (33%). The reduction in car mode share has been largest in Vienna (40% in 1993 to 27% in 2012). Car mode share in the other four cities declined as well: 40–33% in Munich, 39–30% in Zurich, 48–42% in Hamburg, and 35–30% in Berlin.

Four of the five case study cities in this article have travel survey data spatially disaggregated enough to compare travel behaviour in the city centre, the rest of the city,

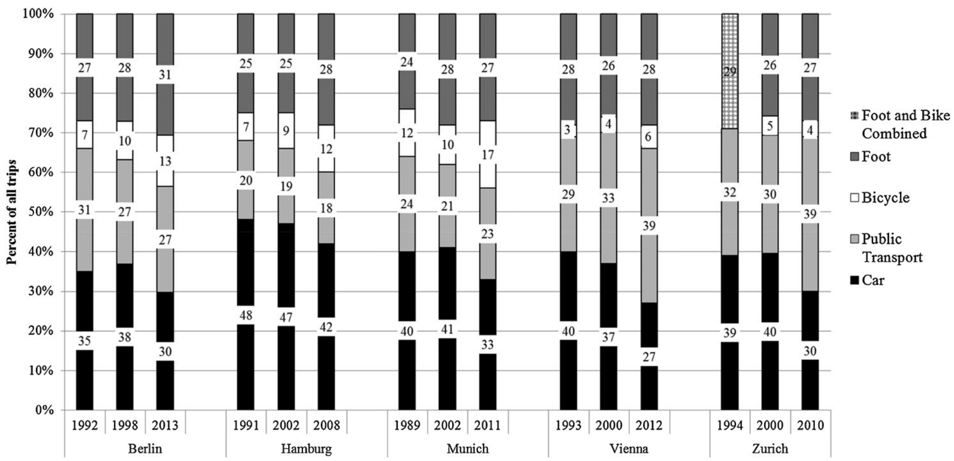

Figure 4. Trend in percentage of daily trips by car, public transport, bicycle, or foot in Berlin, Hamburg, Munich, Vienna, and Zurich (1990–2013).

Notes: These travel surveys only report trips made by city residents, thus excluding suburban residents as well as visitors to the city. As noted in Figure 5, car use is considerably higher in the suburbs than shown here for city residents alone. Only approximate comparisons can be made among the five cities because the available travel surveys vary in methodology and timing. As noted in Figure 2, these travel surveys only report the main mode of transport for a trip and not the short access trips by other modes. This especially underestimates the share of walk trips in all cities. Zurich data for 1994 combine the modal share for walking and cycling.

Sources: BMVBS (2010), City of Berlin (2014a), City of Munich (2015b), City of Zurich (1990–2014), Kalender (2012), Krause (2009), Omnitrend (2015), Pirhofer and Stimmer (2007), Socialdata (2015), and Staedtepegel (2007).

and the suburbs. As shown in Figure 5, car mode share rises in all four of the cities from the city centre to the outer ring of the city, and is even higher in the suburbs. Conversely, the combined share of walking, cycling, and public transport falls from the centre toward the periphery. The existing literature suggests that this is the usual spatial variation in cities of Western Europe, North America, and Australia (De Palma & Rochet, 2000; Ewing & Cervero, 2010; Pucher & Buehler, 2012; Saelens, Sallis, & Frank, 2003; Vandenbulcke et al., 2011). The higher density, mixed-use land-use pattern, shorter trip distances, narrower and more congested streets, proximity to frequent public transport, and difficulty (and high cost) of car parking in the city centre all help explain lower levels of car ownership and use there. Correspondingly, the existing literature shows that levels of walking are highest in the city centre, falling from there to the city periphery, and lowest in the suburbs. Similarly, bike use is generally highest in the centre of the city or in the intermediate ring, and falls off sharply toward the city periphery and suburbs.

In contrast to that general pattern, bicycle use in Hamburg, Berlin, Munich, and Vienna is just about the same in outer portions of the cities and in the suburbs as in the city centre. Comparable travel mode distributions are not available for Zurich, but the Swiss National Travel Survey reports that, in aggregate, Swiss suburbs have higher bike mode share than Swiss cities (BFS, 2011). The spatially disaggregated travel surveys suggest that, although decentralised (usually along public transport lines), suburbs of all five case study cities

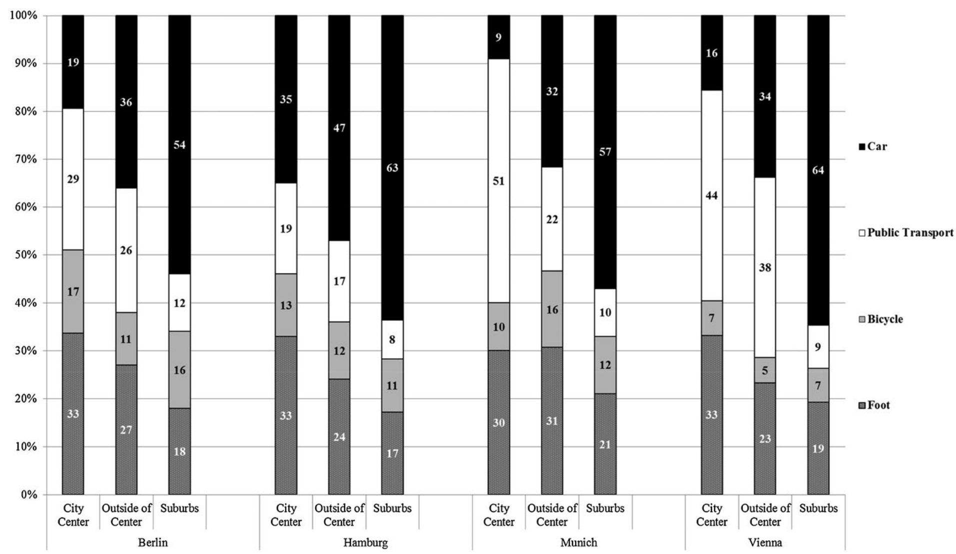

Figure 5. Spatial variability in percentage of daily trips by car, public transport, bicycle, or foot, 2008–2012.

Notes: In contrast to Figure 4, the modal distributions in Figure 5 include suburban residents of the same metropolitan area, as shown in a separate category. The category "outside of centre" is still within the political city limits, but outside the city centre. The category "city centre" refers to the core area or inner city, which is differently defined in each of the four cities. In Munich, it is the area within the "Altstadtring"; in Vienna, it includes inner districts 1–9 and 20; in Berlin, it includes the area in the so-called "Hundekopf"; and in Hamburg it includes the city's own officially designated "Kerngebiet". Sources: Calculations by authors based on (BMVBS, 2010; City of Berlin, 2014a; Omnitrend, 2015; Socialdata, 2015) and information collected directly by the authors from each of the five cities.

have compact, mixed-use land-use patterns generating trips short enough to make by bike. In contrast, the walking and public transport shares of trips fall with distance from the centre.

In short, there is important spatial variation in travel behaviour within each of the metropolitan areas, with much greater use of sustainable transport modes in the centre and far more reliance on the private car with distance from the centre, especially in the suburbs. Our data do not permit a spatial regression analysis that would allow a rigorous examination of the reasons for the spatial variation. As indicated by other studies, however, it seems likely that the higher density and more mixed-use development in the city centre generate many short trips that can be made by walking, thus explaining the higher walk mode share in the centre. The much greater availability, frequency, and proximity of public transport services in the city centre helps explain the higher mode share of public transport there. Suburban residents use public transport mainly for daily rail commutation trips to jobs in the city centre and for less frequent travel for shopping, specialised services, cultural activities, and recreation in the city centre.

Public policies that reduced car dependence

There is no single policy measure that alone can explain the decline in car use in the five case study cities. That is consistent with an extensive literature documenting the need for a coordinated set of transport, housing, land-use, and taxation policies to induce a modal shift from the private car to walking, cycling, and public transport (Arnott et al., 2014; Cervero, 1998; Newman & Kenworthy, 2015; Pucher, Dill, & Handy, 2010; UN Habitat, 2013; Van Wee, Annema, & Banister, 2013).

Comprehensive, multi-modal transport planning evolved over decades in the five case study cities, starting in the 1970s and 1980s. There was also a steady shift from roadway construction to promoting walking, cycling, and public transport. Rapid increases in car use in cities throughout Western Europe had been causing worsening problems of congestion, air pollution, noise, parking overflow, traffic injuries and fatalities, and reduced viability of businesses in the city centre. In combination with the energy crises and increasing environmental awareness in the 1970s, these problems highlighted the need to restrict car use and mitigate its many adverse impacts. They generated the public and political support necessary to implement the necessary policies.

In the sections that follow, we group by mode the measures undertaken in the five cities to improve walking, cycling, and public transport and the restrictive measures implemented to discourage car use. The focus is on policies during the period from 1990 to 2015, but many of the policies are refinements and expansions of policies first implemented in the 1970s or 1980s, as noted in such instances.

Walking

Although walking is the oldest and most fundamental of transport modes, only in recent decades has it gotten the attention it deserves. Conditions for walking in European cities have been far superior to those in North America and Australia, but even in Europe, pedestrians were largely ignored or marginalised in the car-oriented transport plans of the

Table 2. Policies that promote walking in the case study cities.

Car-free pedestrian zones
Vienna, Munich, and Zurich introduced pedestrian zones in the 1970s; considerable expansion since then, with city cores now mostly car-free
Number of pedestrian zones: Munich (22), Hamburg (20), and Berlin (16)
Total length of pedestrian streets and plazas: Munich (6 km), Hamburg (7 km), Zurich (11 km)
Total area of pedestrian zones in 2014: Hamburg (103,223 m^2); Vienna (295,938 m^2, tripled since 1990)
Traffic calming[a]
All five cities have traffic calmed (speed limit of 30km/h or less) an increasing percentage of streets over time, especially since 1990
Percentage of roadway network traffic calmed: Munich (85%), Berlin (78%), Vienna (75%), Zurich (50%), Hamburg (50%)
All cities have plans to traffic-calm almost all residential streets in future years
Play streets/home zones
Munich, Hamburg, and Berlin have many "play streets" (speed limit of 10km/h or less) in neighbourhoods, but cities do not have statistics about their number and extent because they are often part of overall traffic-calming schemes
Vienna tripled the length of its "play streets" from 11 km in 1990 to 32 km in 2013
Shared streets/encounter zones
Length of shared streets, with a speed limit of 20 km/h: Zurich (17 km) and Vienna (3 km)
Berlin has three shared street pilot projects. Hamburg has planned for at least one "shared space" in each of the seven city districts
Improving walking facilities[b]
Widening of sidewalks and improvement of sidewalk surface, lowering of curbs, better street furniture, trees and shrubs, and human-scale lighting
Improvements in street crossings and intersections: highly visible zebra stripes with improved lighting, raised crosswalks at intersections to slow cars, median refuge islands, pedestrian-activated crossing lights, and curb extensions to shorten the length of the road crossing by widening the sidewalk at crosswalks
Reduced wait times for pedestrian crossing lights and more time for pedestrians to cross
Mid-block cut-through walkways for pedestrians on long blocks
Signage and accessibility for all
Improved directional signs for pedestrians indicating the direction and distance to important locations
In Hamburg's central city, signs at 300 locations indicate directions and distance to various points of interest, cultural attractions, rail transit stations, and ferry terminals
Berlin improved signage for children to guide them to school and other destinations
Removal of barriers to facilitate access by people in wheelchairs, walking baby carriages, and anyone with a mobility disability
Wheelchair accessibility is a goal in every new roadway, sidewalk, and plaza construction project
Education and enforcement
Mandatory traffic education in most schools
Rigorous training and testing of motorists to obtain a driver's licence
Most residents obey no-walk signals due to training in schools and enforcement by police and parents
Strict enforcement of traffic laws for motorists to protect pedestrians, including speed limits, parking, and yielding to pedestrians

[a]Traffic calming reduces the legal speed limit to 30 km/h or less on particular streets. This can be done either with posted speed limits alone or in combination with a wide range of infrastructure changes to the street. Some of these infrastructure changes make it impossible for motorists to drive from one side of the neighbourhood to the other. Even streets without such infrastructure changes discourage through traffic due to the lower speed limit, which encourages through traffic to use higher speed arterials at the edges of neighbourhoods. Traffic calming reduces the speed of traffic and traffic volumes. Thus, it increases the safety of neighbourhood streets, while also reducing noise and air pollution. Play streets/home zones and shared streets/encounter zones are two special types of traffic calming. Play streets/home zones reduce the legal speed limit to 10 km/h or less and often include infrastructure modifications to the street. Shared streets/encounter zones impose a speed limit of 20 km/h. Both shared streets/encounter zones and play streets/home zones give pedestrians and cyclists the same right as motorists to use the entire width of the street.

[b]Many of these improved infrastructure measures for pedestrians can also be included as part of traffic-calming schemes. But they are found throughout the cities, even in areas with no traffic calming and along major arterials with much higher speed limits.

Sources: City of Berlin (2013, 2014a), City of Hamburg (2015b), City of Munich (2012, 2015a), City of Vienna (2014b), City of Zurich (2014), Hass-Klau (1993, 2015).

1950s and 1960s (Banister, 2005; Hass-Klau, 1993, 2015). Already in the 1970s, many European cities realised the crucial importance of good walking facilities for the viability of a city, and with each decade since then, pedestrian facilities have been expanded and improved (Pucher & Dijkstra, 2003).

As shown in Table 2, each of the five case study cities has implemented a wide range of policies to promote walking, but the emphasis has varied from one city to another. Perhaps the most visible evidence of improved pedestrian facilities has been the establishment of car-free pedestrian zones. Available statistics on the extent of pedestrian zones are not entirely comparable, but they suggest that Vienna and Zurich have the largest (see Table 2). While pedestrian zones tend to be most important in city centres – and some outlying sub-centres – traffic calming is widespread. This involves not only the imposition of a 30 km/h speed limit on cars but also the partial redesign of streets, through physical infrastructure modifications to reduce car speeds even without police enforcement (e.g. street narrowing, on-street car parking on alternate sides, speed humps and speed tables, chicanes, and diverters). All five cities have traffic calmed an increasing percentage of their streets, especially since 1990. As of 2013, Munich, Berlin, and Vienna had traffic calmed about 80% of their road networks compared to 50% in Zurich and Hamburg, with plans for future increases in all cities.

Further advancing the goal of traffic calming, most German, Austrian, and Swiss cities have been experimenting with various versions of shared streets, which generally have a lower speed limit (10–20 km/h) and give pedestrians and cyclists the legal right to use the entire width of the street. In addition, motorists are required to drive with special care to avoid endangering non-motorists (Hass-Klau, 2015; Pucher & Buehler, 2008).

There are many other measures that have been undertaken by all five of the cities over the past few decades to improve walking conditions (see Table 2). For example, the quality of the sidewalk environment has generally been improved, with better street furniture, improved pavement, installation of trees and shrubs, better human-scale lighting (vs. roadway lights at the top of tall poles), and often wider sidewalks. All five of the cities have set as a goal the removal of barriers to facilitate use by people in wheelchairs, walking baby carriages, and anyone with a mobility disability. In addition, tactile guidance strips are increasingly being introduced for the sight-impaired.

All five cities have made numerous improvements in pedestrian facilities for crossing streets and intersections. Crosswalks have been made safer and more convenient by adding highly visible zebra stripes, with crosswalks sometimes raised from the street surface to slow cars. Other improvements to crosswalks include median refuge islands, better lighting, pedestrian-activated crossing lights, and curb extensions that shorten the length of the road crossing by widening the sidewalk at crosswalks. Similar techniques are used at intersections – especially curb extensions, zebra crosswalks, better lighting, and sometimes speed tables, which raise the level of the entire intersection, thus slowing down cars. In addition, some cities are reducing wait times for the pedestrian crossing light and lengthening the time for pedestrians to cross (see Table 2).

All five cities have implemented many of these improved infrastructure measures for pedestrians as part of traffic-calming schemes. They are, however, by no means limited to traffic-calmed areas. Indeed, they can be found throughout the cities, even in areas with no traffic calming and along major arterials with much higher speed limits.

In spite of increases in income, car ownership, and trip distances since 1990, the walk share of daily trips has increased or remained stable in all five cities, with similar levels in the latest survey year (27–31%). Moreover, the reported walk share of daily trips, as measured by travel surveys, almost certainly underestimates total walking levels. Most city travel surveys undercount total walk trips because they do not capture short trips on foot made to access other modes, especially public transport, which is primarily accessed on foot. As walking levels have increased or remained stable, pedestrian safety has greatly improved, with a dramatic reduction in fatalities. Between 1990 and 2013, for example, pedestrian traffic fatalities fell by 68% in Munich and 85% in Berlin (City of Berlin, 2013; City of Munich, 2015a).

Cycling

Munich clearly outshines the other cities when it comes to cycling. In the most recent survey year, 17% of trips in Munich were by bike, compared to 13% in Berlin, 12% in Hamburg, 6% in Vienna, and 4% Zurich (see Figure 3). For all of the cities, however, the share of trips by bike has increased over the past few decades. Since the mid-1970s, the bike share of trips has tripled in Munich and roughly doubled in Berlin, Hamburg, and Vienna, while only slightly increasing in Zurich. The growth in cycling has been facilitated by the expansion and improvement in cycling facilities, bike parking, integration with public transport, cycling safety and training in the schools, and a wide range of promotional programmes (see Table 3).

The much lower bike mode shares in Vienna and Zurich are due to several factors: (1) Both Vienna and Zurich have long traditions of walking and using public transit, and cycling has not been part of their transport culture. The superb transit systems in Vienna and Zurich out-compete cycling in most cases, especially with inexpensive monthly, semester, and annual passes, which make the marginal price of a transit trip zero; (2) Parts of Vienna and Zurich are hilly and not conducive to cycling, while Berlin, Hamburg, and Munich are mostly flat; (3) Only over the past 10 or so years has Vienna greatly increased investment in its cycling infrastructure, which remains less extensive, less well connected, and lower quality than in the 3 German cities. Likewise, cycling infrastructure has been neglected in Zurich, leading to an incomplete network with many gaps. The increases in bike mode share in Zurich and Vienna over the past two decades have been due to expansions in bike infrastructure, but both cities are decades behind Munich, Hamburg, and Berlin, which were heavily investing in bike infrastructure already in the 1970s.

The statistics on the extent of cycling facilities in the five cities shown in Table 3 are not directly comparable. In particular, they do not reflect the different age, design, type, and quality of cycling facilities. Nevertheless, all cities report expansion and improvement in cycling facilities over recent decades (see Table 3). Most of the cycling facilities in Munich are newer and better designed than in Hamburg and Berlin. Both Hamburg and Berlin already had extensive bikeway networks in the 1970s, but many of their facilities were old and substandard (City of Berlin, 2014b; City of Hamburg, 1999/2007; Pucher & Buehler, 2008). Thus, much of the effort in Berlin and Hamburg has been invested in upgrading and widening existing facilities and improving intersection treatments to enhance safety.

In all the cities, many bike routes are on lightly travelled, traffic-calmed residential streets with directional signage for bikes but without separate bike facilities. Such routes have become increasingly important as all five cities have raised the percentage of their roadway networks that is traffic calmed to 30 km or less. The five cities permit bi-directional cycling on many one-way traffic-calmed streets, but with special signage

Table 3. Policies that promote cycling in the case study cities.

Bike route networks
Expansion of bikeway networks 1990–2012: 190–1200 km in Vienna; 750–1400 km in Munich; 150–340 km in Zurich
Hamburg and Berlin mainly focused on upgrading and widening existing facilities and improving intersection treatments to enhance safety along their already extensive bike networks mostly built from 1960 to 1990 (1700 km in Hamburg; 3500 km in Berlin)
Km of bike routes per 100,000 inhabitants: Hamburg, Berlin, Munich (~100 km), Zurich (85 km), and Vienna (67 km)
On-road bike lanes
In Berlin on-street bike lanes increased from 50 km in 2002 to 174 km in 2012; combination bus–bike lanes rose from 50 to 80 km
Hamburg has built over 100 km of on-street bike lanes since 2000, with more planned
About 40% of Munich's bicycle network are painted on-street bike lanes (~500 km) compared to 25% of Vienna's network (~300 km)
Traffic calming, bicycle priority streets, and shared-use paths
Many bike routes on lightly travelled, traffic-calmed residential streets
All five cities have raised the share of their roadway network that is traffic calmed to 30 km/h or less
All five cities permit bi-directional cycling on many one-way traffic-calmed streets, often with special signage alerting motorists of cyclists riding in the opposite direction
Number of bicycle priority streets with minimal car traffic and cyclist right of way over the entire street: Munich (55), Berlin (16), and Hamburg (7)
In all five cities, there are extensive mixed-use paths shared by cyclists and pedestrians, especially in parks and agricultural areas within the city (e.g. 260 km in Munich)
Signage and branding of bike routes
Varying street markings, pavement colour, and route designations depending on type of route
Munich has 4000 signs at over 750 intersections, indicating direction, distance, route number, and connections
60% of Zurich's bike routes have uniformly designed directional signs for bikes
Berlin and Hamburg are building specially marked radial bike routes for long-distance bike trips from the outer portions of the city to the centre
Route planning
Online bike route planners enable the choice of optimal routes based on preferences of the traveller regarding directness of route, speed, on-road vs. off-road facilities, and the availability of bike parking and bike sharing facilities, conveniently accessed via smartphone technology
Bike sharing
Munich, Berlin, and Hamburg have versions of German railway's (DB) Call-a-Bike programme with 1260, 1750, and 1650 bicycles, respectively. Hamburg and Berlin have 129 and 130 docking stations for bikes, while Munich has a free-floating system without docking stations, where bikes can be returned to any major intersection in the middle ring of the city
Munich and Berlin each has 300 NextBike bike sharing bikes in addition to DB's Call-a-Bikes
Vienna's CityBike system offers 1200 bikes at 96 docking stations
In Vienna the first hour of bike use is free, compared to only the first 30 minutes for the Call-a-Bike and Next Bike systems
Zurich's bike-rental programme is free of charge and offers a variety of 300 bicycles, including e-bikes, cargo bikes, and bicycles with children's seat
Bike parking
Number of bike parking spaces (2012): Munich (33,000 bike parking spaces in public spaces and 50,000 bike parking spaces at public transport stops throughout the region), Berlin (26,600 bike parking spaces at U-Bahn and S-Bahn rail stations), Hamburg (26,000 bike parking spaces at 235 bike-and-ride lots along rail lines), Vienna (32,000 bike racks in public spaces), Zurich (17,200 bike racks in public spaces and 2,400 bike parking spaces at train stations)
Full-service bike parking stations and secure lockers: Hamburg (1 full-service bike parking station, 6 bike parking garages at key rail stations, and 710 secure bike lockers), Berlin (1 full-service bike parking station with 566 spaces in Bernau), Zurich (2100 bike parking spaces in 5 bike stations and 300 secure bike lockers at train stations)
Zoning ordinances require that newly constructed buildings above a certain size provide a prescribed minimum number of bike parking spaces, based either on the number of residential apartments or the number of workers in commercial buildings
Hamburg has 340 bike parking sheds (12 parking spaces each) in neighbourhoods throughout the city to provide sheltered, secure bike parking for an annual fee of 250 Euros
Promotional events and education
Traffic safety lessons in schools, first in the classroom, then on special training test tracks, and then on regular streets – often supervised by police officers
Voluntary cycling training courses specially adapted for adults, seniors, and new residents or immigrants from countries without a tradition of cycling
Large promotional public bicycling events
Mass bike rides: Berlin's annual "Sternfahrt" attracted 200,000 bicyclists in 2014; Hamburg's "Sternfahrt" attracted 20,000 riders in 2014
As part of Munich's campaign to become Germany's cycling capital, the city offers special bike tours for new residents, bike fashion shows, bike-theme film competitions, car-free roads in the city centre for night bike rides in the summer, and bike flea markets, where used bikes can be sold and purchased

Vienna has a special mobility agency for coordination of bicycle promotion
Zurich installed 36 free air pumps around the city for cyclists

Staffing and funding

Munich had 11 full-time city staff working on bicycling issues in 2014. Between 2009 and 2014, the city tripled its annual expenditures on cycling infrastructure and programmes from 1.5 million Euros to 4.5 million Euros. From 1992 to 2014, the city invested 32 million Euros in cycling. In 2015, the city council decided to increase funding for cycling to 10 million per year

Zurich recently adopted a new master plan for cycling which includes about 50 different measures, improving cycling infrastructure as well as expanding various pro-bike programmes with approved funding of 110 million Euros over the next decade

Berlin increased annual expenditures on cycling infrastructure and programmes from one million Euros in 1995 to 15 million Euros in 2015

Sources: City of Berlin (2014a, 2014b), City of Hamburg (1999/2007), City of Munich (2015c), City of Vienna (2014b), City of Zurich (1990–2014), Northern Germany Statistics (2014), and Pucher and Buehler (2008).

alerting motorists of cyclists riding in the opposite direction to cars. An especially innovative development – pioneered in Germany – is the establishment of bicycle streets – narrow streets with minimal or no car traffic where cyclists have right of way over the entire width of the street. In all five cities, there are extensive mixed-use paths shared by cyclists and pedestrians, especially in parks, nature preserves, and agricultural areas within the city. On such paths, pedestrians have priority over cyclists unless there are pavement markings specifically allocating space between pedestrians and cyclists.

The upgrade in the quality of virtually all cycling facilities – both off-road and on-road – is not reflected in the statistics. One aspect of this upgrade is the installation of way-finding signage for cyclists indicating the direction and distance to other locations as well as route labelling (see Table 3). Both Berlin and Hamburg are building specially marked radial bike routes for long-distance bike trips from the outer portions of the city to the centre. All five cities have online bike route planners that enable the choice of optimal routes based on the preferences of the traveller regarding directness of route, speed, on-road vs. off-road facilities, and the availability of bike parking and bike sharing facilities. The nearly universal availability of smart phones with internet access has greatly enhanced the convenience and flexibility of such online route planning.

All five cities have been expanding the supply of public bike parking and improving its quality and security (see Table 3). In addition to these publicly provided parking spaces, all five cities have requirements that newly constructed buildings above a certain size provide a prescribed minimum number of bike parking spaces, based either on the number of residential apartments or the number of workers in commercial buildings. Moreover, the German cities and Vienna have implemented and expanded modern bike sharing systems with currently over 1200 bike sharing bicycles in each city. Zurich has a free bike-rental programme with 300 bicycles, but plans to introduce a modern bike sharing system.

An important aspect of cycling promotion and safety is traffic education in the schools (Pucher & Buehler, 2008). There are variations from city to city, but most schools include cycling training as part of traffic education. In addition, most of the cities offer voluntary cycling training courses especially adapted for adults, seniors, new residents, and immigrants from countries without a tradition of cycling.

There is a wide range of informational and promotional programmes and events in the five cities to engender enthusiasm and interest in cycling. As shown in Table 3, these efforts range from individual one-day events to fully coordinated year-long city-wide campaigns to increase cycling. In addition, all five cities have devoted increasing amounts of money and personnel to encouraging more and safer cycling.

Public transport

Walking and cycling both depend on a good, extensive, affordable public transport network as an alternative to the car for trips that are too long to make by walking or cycling. Conversely, public transport depends on walking to get most passengers to and from public transport stops. Cycling can greatly expand the service radius of public transport stops, but for some trips of intermediate or short distance, cycling competes with public transport.

All five cities provide public transport through a fully integrated, region-wide system of public transport operators called a "Verkehrsverbund". Hamburg was the first metropolitan area to form a Verkehrsverbund (in 1967), but the other four cities followed: Munich (1972), Vienna (1984), Zurich (1990), and Berlin (1999) (Krause, 2009; VDV, 2009). Since trips on public transport often cross the boundaries of local jurisdictions within metropolitan areas, it is crucial to coordinate fares, ticketing systems, routes, timetables, and different modes of public transport throughout the entire region. Without exception, the creation and expansion of Verkehrsverbünde has led to increased public transport passenger trips – both total and per capita – in each of the five metropolitan areas examined in this article.

In contrast to the city travel surveys shown in Figure 4, the regional public transport systems (Verkehrsverbund) report the number of passengers throughout the metropolitan area and include residents as well as non-residents (such as visitors). Public transport use per capita increased in all five Verkehrsverbund service areas: +24% in Hamburg, +11% in Munich, +22% in Vienna, and +35% in Zurich (from 1990 to 2012); and +28% in Berlin (1995–2012). In 2012 Zurich's Verkehrsverbund had roughly a third more passengers per capita than Vienna (438 vs. 318) and roughly twice as many passengers per capita as in Munich (239), Berlin (222), and Hamburg (209).

It is noteworthy that public transport trips in the three German Verkehrsverbund service areas increased considerably even though the share of trips by public transport within the cities of their metropolitan areas fell slightly, as shown in Figure 4. The two statistics refer to different geographic areas (city vs. extended metropolitan area) and measure different things (number of public transport trips vs. public transport share of trips by all modes). In combination, these different statistics suggest that in the German cities many short trips are now being made by walking or cycling, while longer trips between the suburbs to the central cities are generating the increase in overall public transport use for the region as a whole.

All five of the Verkehrsverbünde have increased the amount of public transport service supplied, as measured by "place kilometres of service per capita". That statistic reflects total seating and standing capacity of vehicles as well as the number of kilometres all the vehicles in the fleet cover each year. It also adjusts for the increasing population of expanded service areas. From 1990 to 2012, the increases in service supply were 59% in Munich, 46% in Vienna, 36% in Hamburg, and 21% in Zurich (see Table 4). The increase in Berlin's Verkehrsverbund (founded in 1999) was 1% from 2000 to 2012. Expanded service over a larger Verkehrsverbund area has not only increased the total amount of

Table 4. Policies that promote public transport in the case study cities.

Expanded service supply

- Increase in place kilometres of service per year (1990–2012): Munich (88%), Hamburg (86%), Vienna (74%), and Zurich (36%)
- Increase in place kilometres of service per capita per year (1990–2012): Munich (59%; 8200–13,100 km), Vienna (46%; 10,600–15,400 km), Hamburg (36%; 7700–10,500 km), Zurich (21%; 12,000–18,000 km); from 2000 to 2012 in Berlin (1%; 9000–9200 km)
- Expanded route km of urban rail systems (U-Bahnen) (1990–2012): Vienna (41–76 km: 85%); Munich (63–103 km: 63%); Hamburg (90–104 km: 16%), Berlin (134–146 km: 9%)
- Expanded regional rail service (S-Bahnen and Regionalbahnen) (1990–2012): Munich (9.0–21.2 billion place km: 135%), Vienna (14.3–22.5 billion place km: 58%), Hamburg (887–1302 route km: 46% (2000–2012 only)), Zurich (13.0–22.1 million vehicle km: 70%), and Berlin (276–396 route km: 43% (2000–2012 only))
- Extent of tram networks in 2012: Berlin (191 km), Vienna (172 km), Zurich (119 km), Munich (79 km), and Hamburg (0 km)
- Expansion of regional bus services (mainly in the suburbs): Munich (0.8 billion place km in 1990 to 2.2 million place km in 2012: 146%) and Hamburg (5.7 billion place km in 2000 to 8.7 billion place km in 2012: 51%)
- Expansion of separate bus lanes to avoid delays from roadway congestion: Berlin (67 km in 1992 to 101 km in 2012) and Hamburg (22 km in 1987 to 31 km in 2009). In 2014, Munich had 22 km of exclusive bus lanes

Improved quality of service

- Verkehrsverbünde have steadily expanded their service area and improved coordination of public transport services and fares throughout the metropolitan region and even beyond the region to include entire states
- All five cities modernised buses and trains, making them more comfortable, more attractive, including special features such as on-board WIFI and real-time information. Bus and rail stops have also been modernised, improving comfort and safety while providing more information to the passenger. Rail stops usually include real-time arrival and departure information
- Physical connections between different bus and rail routes have been improved, and schedules coordinated, thus making transfers faster and easier
- All five of the Verkehrsverbünde have fully multi-modal, real-time, interactive online trip planners that help travellers to find the best origin-to-destination public transport routing, including access to public transport by foot, bike, and car at both ends of the trip
- All five Verkehrsverbünde conduct citizen surveys to monitor satisfaction with public transport service, generally on a scale from 1 to 6: Hamburg (3.2 in 1994 and 2.5 in 2014), Munich (2.8 in both 1996 and 2014), Berlin (2.7 for first survey in 2014), Vienna (2.4 in 1996 and 1.8 in 2014 (on a scale from 1 to 5)); for Zurich satisfaction rose from 73 points in 2000 to 77 points in 2012 (with a maximum of 100 points)

More attractive fare systems for regular users

- Share of passenger trips by holders of monthly, annual, and semester tickets: ~80% in German cities and ~90% of all trips in the Vienna region
- Price of a monthly ticket: Vienna (€48), Munich (€64), Zurich (70SFR/~€68), Berlin (€74), and Hamburg (€76)
- Number of single tickets to equal price of a monthly ticket: Hamburg (27), Munich (26), Vienna (27), Berlin (31), and Zurich (19)
- Price of annual ticket: Vienna (€365), Zurich (SFR630/~€610), Munich (€642), Hamburg (€726), and Berlin (€740)
- Price of annual ticket as % of GDP per capita: Vienna (0.8%), Zurich (0.8%), Munich (1.1%), Hamburg (1.4%), and Berlin (2.5%)
- Number of monthly tickets to equal cost of annual ticket: Vienna (8), Zurich (9), and 10 months in the German cities
- Additional discounts for senior and student tickets compared to regular monthly tickets: 42% and 53% in Hamburg; 35% and 64% in Berlin; 40% and 30% in Munich; 46% and 28% in Zurich; 61% and 83% in Vienna
- Both single and monthly ticket prices have risen in all five of the Verkehrsverbünde over the period 1990–2012, but gasoline prices have increased about 1.5 times faster
- Percentage of operating expenses covered by passenger fares: 80% for Munich, 74% for Berlin, 72% for Hamburg, 63% for Zurich, 55% for Vienna

Sources: Buehler, Zimmerman, and Lukacs (2015), HVV (1990–2013), MVV (1990–2013), VBB (2000–2014), VOR (1990–2013); and ZVV (2014).

service but has also provided riders with more connections, more route options, and more extensive geographic coverage. Since they were founded, the Verkehrsverbünde have been continuously improving the coordination of public transport services and fares throughout the metropolitan region.

The Verkehrsverbünde offer rail services of various kinds: U-Bahn (metros mainly within political boundaries of the city); S-Bahn (mainly radial trips from the suburbs to the city, but also used for trips within the city); Regionalbahn (longer-distance trips to further-out suburbs and nearby cities in the region); and Strassenbahn (tram or light rail, mainly within the city). In addition to rail system expansions, vehicles and stations have been modernised throughout all five metropolitan areas. In addition, the Strassenbahn has been speeded up through priority traffic signals. Verkehrsverbünde have also improved their bus services by modernising the vehicle fleet with low-floor vehicles and by expanding their networks of bus-only lanes, priority traffic signals for buses at intersections, and express services (including some bus rapid transit) (see Table 4).

At the same time as public transport services have been expanded and improved, fare systems have been better coordinated and made easier to use and less expensive, especially for regular passengers (see Table 4). Monthly, annual, and semester tickets have been so attractively priced that most passenger trips in all five cities are now made by holders of such tickets (see Table 4). Annual tickets have become popular because they offer a further discount off the cost of monthly tickets. Assuming an average of ten trips per week, annual tickets offer a discount of two-thirds to three-fourths off the price of a single ticket depending on which city. As shown in Table 4, seniors and students benefit from even more deeply discounted monthly or semester fares.

Averaged over the five cities, the price of single tickets (+74%) and monthly tickets (+70%) rose from 1990 to 2012, but that was less than half of the average increase in gasoline prices (+169%). Thus, relative to the price of gasoline, public transport fares became considerably less expensive. The attractive fares in all five cities have been made possible by operating subsidies. As shown in Table 4, the extraordinarily low price of annual tickets in Vienna (€356) comes at the cost of larger operating subsidies, which cover 45% of operating costs. The higher ticket prices in the German cities, ranging from €642 in Munich to €740 in Berlin, require smaller subsidies as a percentage of operating costs, ranging from 20% in Munich to 28% in Hamburg.

Four of the five cities have surveyed residents over the past two decades to determine how satisfied they are with public transport services. Although these ratings of public transport systems in different cities are subjective and not directly comparable, they are a useful barometer of service quality over time in each city. Overall, the citizen surveys suggest a large improvement in Vienna, some improvement in Zurich and Hamburg, and no change in Munich (see Table 4).

Taxation, fees, and car-restrictive policies

The high prices of petrol in Germany, Austria, and Switzerland are mostly due to federal taxes, which account for about two-thirds of the retail price, greatly increasing the cost of driving (see Table 5). Federal taxes and fees on new car purchases and ownership increase the cost of purchasing and owning a car, thus directly discouraging car ownership, but indirectly discouraging car use as well. Including sales taxes, registration fees, motorway tolls, import fees, and gasoline taxes, the total annual taxes paid in 2009 for a small Volkswagen Golf (1.6 L gasoline engine) were estimated at €1690 in Austria, €1520 for Germany, and €1240 for Switzerland (DIW, 2009). The corresponding taxes and fees for larger cars were much higher.

Driver licencing is also regulated at the federal level in all three countries, with extensive training and strict testing required for obtaining a licence. In general, the age for obtaining

Table 5. Policies that restrict car use and make it more costly in the case study cities.

National government policies increase cost of car ownership and use
Share of taxes in gasoline retail price: 56% in Germany, 49% in Switzerland, and 48% in Austria
Increase in gasoline (petrol) prices (1990–2012): 178% in Switzerland, 170% in Germany, and 155% in Austria
Total annual taxes paid in 2009 for a small Volkswagen Golf (1.6 L gasoline engine): €1690 in Austria, €1520 for Germany, and €1240 for Switzerland. Taxes and fees for larger cars were much higher
Driver licencing is regulated at the federal level in all three countries, with extensive training and strict testing required to obtain a licence, including a 2- or 3-year probation period, and a minimum age of 17 or 18 years old
In Germany and Austria there are a required minimum number of hours of private driving lessons, which cost about €1200–1700 (on top of about €200 for licence fees) depending on the country and whether or not the licence applicant passes the test on the first try or fails and is required to take additional lessons before taking the test a second time
Local government restrictions on car use
Car-free pedestrian zones prohibit motor vehicle use, except at certain restricted times (e.g. commercial delivery vans)
Traffic-calmed residential streets make car use slower, more circuitous, bumpier, and less convenient
Diverters and other on-street barriers (e.g. bollards) discourage through traffic on local streets
Berlin and Munich have designated parts of their central city as Umweltzonen (environmental zones) which only permit use of especially low-emission cars
Parking a car has become more difficult and more expensive since 1990
Reduction in total supply of on-street parking spaces, sometimes off-set by construction of off street parking garages
City-wide parking time limitations of 1–2 h for on-street parking, except for residents
Parking management in all five cities: coordination of parking supply, price, and duration. Since 1990, parking management has expanded from the city centres to include almost the entire city, while parking prices have increased
While roadway construction has been restricted in city centres, all five of the cities have invested heavily in building circumferential roadways to divert traffic around the city centre
Especially in Vienna and Zurich, limited supply of motorways and major arterials within the city makes it difficult to access the central city by car, thus encouraging more public transport use. Limited motorway construction within cities has prevented the destruction of central city neighbourhoods

Sources: City of Berlin (2015a), City of Hamburg (2015b), City of Munich (2015d), City of Vienna (2015b), and City of Zurich (2014).

a licence is 18, but Germany issues temporary licences at the age of 17 years, which require a licenced adult to accompany the driver. The average cost of obtaining a licence, including mandatory driving lessons and fees, ranges from €1400 to €1900 in Germany and Austria. It costs less in Switzerland (€600–€1000) because there are no mandatory driving lessons (European Driving Schools Association, 2015). These national policies lead to a high base cost of car ownership and use, and local policies add further to the cost and inconvenience of driving.

At the local government level, parking charges are the main fee assessed on car use. Local governments also impose restrictions on the supply of parking, the allowed time of parking, speed limits, and car access to certain zones. As discussed in the section on walking, pedestrian zones prohibit car use altogether. Traffic-calmed residential streets make car use slower (30 km/h or less), more circuitous, bumpier, and less convenient. Traffic-calming diverters and dead ends for cars (with pass-throughs for pedestrians and cyclists) are for the explicit purpose of preventing through traffic on local streets. Shared streets (10–20 km/h) further reduce the speed limit for cars and require motorists to share the road with non-motorised users. Bicycle streets (30 km/h) limit motor vehicle access to local residents and businesses and require motorists to yield right of way to bicyclists.

These restrictions on car use make walking and cycling safer and more convenient, partly by providing them with more space. The reduction of through traffic also reduces noise and air pollution in city centres and residential neighbourhoods. Berlin and Munich have also designated parts of their central city as Umweltzonen (environmental zones) which only permit use of especially low-emission cars (UBA, 2015). Such cars must be officially certified in advance and display a special green low-emissions decal on the windshield of the car.

One of the most effective local government efforts to limit car use is through parking management: increasing hourly parking charges toward the city centre and limiting the number of parking spaces and the allowable parking time (see Table 5). In general, cities have imposed time limitations of 1–2 h for on-street parking, but with exceptions for residents and businesses. In general, the closer to the city centre, the shorter the parking time allowed and the higher the price per hour of parking. Fines are charged for not paying the parking charge in advance and for exceeding the maximum allowable parking time. Special residential and commercial parking permits prevent the use of local on-street parking spaces by outsiders driving into the city for work or shopping. Garages and parking lots near the periphery of the city (or in the suburbs) are often located near U-Bahn, S-Bahn or regional rail stations to encourage use of public transport for the trip to the city centre.

In all five cities parking management is a key policy for discouraging car use overall, and in the city centre in particular (see Table 5). Parking management started off in the centres of each of the 5 case study cities and over the past 25 years has expanded to include large portions of the 5 cities, while parking prices have increased. In Zurich there is no free on-street parking at all. Thus, parking a car has become more difficult and more expensive since 1990, an important deterrent to car use.

Limitations on new road construction have also been important. Similar to cities throughout central and northern Europe, there have been few limited access motorways built in cities since the 1980s. Partly due to the massive destruction of German cities in the Second World War, which opened up large areas of undeveloped land, they were able to build more motorways in the 1960s and early 1970s than Vienna and Zurich. Those two cities experienced far less destruction and preserved their historical patterns of buildings and streets, thus sharply restricting the available space for wider or additional roadways. During the 1960s and 1970s, all five cities had plans for even more motorways in the coming years. However, intense public opposition, especially in the 1970s, blocked most motorway plans and provided grassroots support for the car-restrictive policies mentioned in this section as well as the pro-walking, pro-cycling, pro-public transport policies documented in the preceding sections (Csendes & Opll, 2006; Kalender, 2012; Merckens, 2014). Overall, the limited supply of motorways and major arterials in the centres of Vienna, Zurich, Munich, Berlin, and Hamburg has made it more difficult to access the central city by car and avoided the destruction of inner city neighbourhoods that motorway construction would have caused.

While roadway construction has been restricted in city centres, all five of the cities have invested heavily in building circumferential roadways to divert traffic around the city centre and thus reduce congestion, noise, and other traffic problems there. They not only divert traffic around the centre city, but also provide crucial connections to the long-distance motorway network of each country. In some instances, such as Berlin, Vienna, and Hamburg, tunnels serve the same function by removing traffic from centre city streets.

Land use and urban development

Land use and urban development crucially influence travel behaviour, mainly because they are the most important determinant of trip distance, and whether walking, cycling, and public transport are feasible (Ewing & Cervero, 2001, 2010). At the national, state/provincial, and local government levels, Germany, Austria, and Switzerland have coordinated systems of land-use planning which generally discourage low-density development of agricultural land, forests, nature preserves, and other undeveloped greenspace (Alterman, 2001; Buehler, Jung, & Hamre, 2015). Vienna, Munich, Hamburg, Berlin, and Zurich all have formal development plans which specifically encourage mixed-use, compact development focused around public transport lines and well supplied with walking and cycling facilities (City of Berlin, 2015b; City of Hamburg, 2007; City of Munich, 2011; City of Vienna, 2014a; City of Zurich, 2015). They include provisions for building up mixed-use neighbourhood centres throughout the city that enable residents to fulfil most of their daily needs with short trips to nearby shops, schools, and offices. That especially encourages more walking and cycling. With such neighbourhood centres built around rail stations and along tramlines, longer trips can be made by public transport to the city centre for more specialised goods and services.

There are variations from country to country and from city to city. Most importantly, there are large differences between the city and the surrounding metropolitan areas in the degree to which their land-use patterns encourage car use. As already shown in Figure 5, the car share of trips is much higher in the suburbs than in the city centre: 57% vs. 9% in Munich, 64% vs. 16% in Vienna, 54% vs. 19% in Berlin, and 63% vs. 35% in Hamburg. Compact mixed-use development is mainly limited to the cities themselves, with different land-use patterns and travel behaviour in the surrounding region. There are instances of relatively compact mixed-use development in those suburbs centred around rail stations with public transport service to the city. There is considerable population growth in the suburbs, providing the potential to shape new development in a way that is more conducive to walking, cycling and public transport use and less dominated by the car. The future of the suburbs rests on the political will to implement the necessary land-use and transport policies. In spite of this potential, the actual trend over recent decades has been toward more car-dependence in the suburbs, while the shift toward sustainable travel has been restricted mainly to the cities.

Each city has undertaken specific development projects that coordinate land use and transportation to ensure the convenience and safety of walking, cycling, and public transport while discouraging car use (through car-free zones, traffic calming, limited parking, etc.). As part of this strategy, cities have also improved public transport and facilities for walking and cycling.

In Vienna, for example, the modernisation and expansion of the main train station were combined with extensive mixed-use development in and around the renovated station (City of Vienna, 2013, 2015b). On a much larger scale, the City of Vienna is currently building a completely new district (Seestadt) on formerly undeveloped land within the existing city limits (City of Vienna, 2015a). Seestadt is 7 km east of the city centre and, when completed, will be 2.4 km^2 in area, housing 20,000 residents and offering 20,000 jobs. The development is focused along public transport corridors (three rail transit stations with feeder bus services) and will restrict car use, while promoting walking and cycling. There are, however, plans for a new roadway at the northern periphery of Seestadt to connect it with two existing motorways. Thus, Seestadt will also be served by roadways, but not dependent on car use.

Hamburg is currently building a large new mixed-use development (HafenCity) with 6000 new housing units and about 40,000 jobs on the site of a former harbour area (City of Hamburg, 2015a). HafenCity already has a direct metro rail connection to the city centre. The plans for HafenCity include provisions to create a safe, pleasant environment for pedestrians. About 70% of pedestrian walkways will be separated from roadways. Cycling will be encouraged through an integrated network of bike paths and lanes as well as a bike sharing system. HafenCity will have maximum parking allowances for new developments and relegate public car parking garages to the fringes of public spaces to keep cars out and encourage more walking and cycling.

As shown by many studies, minimum parking requirements lead to excess parking supply, make driving cheap and convenient, and thus encourage a shift toward more car use. Implementation of maximum parking allowances is an important recent policy development to discourage car use (Knoflacher, 2007; Shoup, 1999, 2011; Topp, 1993).

Conclusions

As documented in this article, the largest cities in Austria, Switzerland, and Germany have succeeded in reducing the car share of trips over the past 25 years: from 40% to 27% in Vienna, from 40% to 33% in Munich, from 35% to 30% in Berlin, from 39% to 30% in Zurich, and from 48% to 42% in Hamburg. All five cities have implemented a coordinated package of mutually reinforcing transport and land-use policies that, in combination, have made car use slower, less convenient, and more costly, while increasing the safety, convenience, and feasibility of walking, cycling, and public transport.

The specific mix of policies, and relative emphasis among modes, varies from one city to another, reflecting the different situations and preferences in each city. For example, Munich, Berlin, and Hamburg have invested far more, and over a longer period, in cycling infrastructure and programmes than Zurich and Vienna. In each of the five cities, a Verkehrsverbund has been crucial for integrating services, timetables, routes, and fares across all types of public transport throughout the entire metropolitan region. Zurich and Vienna, however, outperform the three German cities by providing more public transport service per capita and offering annual tickets costing less relative to average income (see Table 4). In all five cities parking management has been the most important local government policy to discourage car use, especially in the central city.

The case study analysis in this article cannot prove that the long-term shifts in the cities' transport and land-use policies achieved the observed reductions in car mode share, but they almost certainly played an important role by shifting the monetary and time cost of travel in favour of alternatives to driving. The success of the cities' policy measures is largely attributable to their coordinated implementation, integrated with each other to reap the interactive, synergistic impact of the package of measures as a whole. And that includes, of course, the fully integrated regional public transport systems (Verkehrsverbünde) in each metropolitan area. The importance of integrated policy packages is documented in several studies (Feitelson, 2003; Givoni, Macmillen, Banister, & Feitelson, 2013; Kelly, May, & Jopson, 2008; May & Roberts, 1995).

Shifts in land-use patterns and travel behaviour cannot be explained entirely by government transport and land-use policies. Experts interviewed by the authors suggested that there has also been a qualitative shift in cultural attitudes and preferences toward less reliance on the automobile and increased demand for living in mixed-use, compact developments in or near the city centre. Studies in both North America and Europe similarly suggest underlying changes in lifestyle preferences of the newer generations (Goodwin

& van Dender, 2013; Kuhnimhof et al., 2012; Newman & Kenworthy, 2015). For example, many city centres in Europe and North America have experienced a revival and, in particular, the influx of new residents in their 20s and 30s in neighbourhoods that are amenable to walking, cycling, and public transport use. Studies also suggest that these younger generations are less attracted to cars than their parents, and more willing to walk, bike, and ride public transport.

Although our five case study cities have been successful in reducing car dependence, the story in the suburbs is very different. Travel behaviour and land-use patterns in the suburban parts of their metropolitan areas have remained car-oriented. Transport and land-use policies in suburban areas are usually beyond the control of city governments. Instead, they have been determined by state and local governments less focused on urban development and typically facilitating car use and lower-density development. The role of politics is crucial in developing, adopting, implementing, and disseminating sustainable transport policies, as shown in a forthcoming book dealing exclusively with this topic (Altshuler & Davis, 2016).

The five case study cities demonstrate that it is possible to reduce car dependence even in affluent societies with high levels of car ownership and high expectations for quality of travel. These cities have been especially successful at reducing car dependence, but many of the same policy measures they used have been implemented to varying extents in other European cities. For example, five other major western European cities, all of which are national capitals, have significantly reduced the car mode share of trips since 1990: Paris (−10 percentage points), Copenhagen (−9 percentage points), Amsterdam and London (−8 percentage points), and Stockholm (−7 percentage points) (Buehler & Pucher, in press). Given a mixed-use, compact land-use pattern, an integrated combination of high-quality public transport, walking, and cycling conditions can out-compete the car, gaining back some of the modal share they lost from 1960 to 1990.

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ORCID

Ralph Buehler http://orcid.org/0000-0002-1254-2224
John Pucher http://orcid.org/0000-0002-9499-2383
Regine Gerike http://orcid.org/0000-0002-8063-6636
Thomas Götschi http://orcid.org/0000-0002-1202-7863

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