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Promoting Bicycling in Car-Oriented Cities: Lessons from Washington, DC and Frankfurt Am Main, Germany

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Abstract: This paper compares bicycling in Washington, DC and Frankfurt am Main, Germany, two car-oriented cities that had adapted their urban transport system to car travel during the 20th century. Our comparative case study shows that both cities have been successful in increasing the percentage of trips made by bicycle between the late 1990s and 2018: Washington, DC from 1% to 5% and Frankfurt from 6% to 20% of trips. Both cities had detailed bike plans and specific mode share goals for bicycling. However, those plans were only used as guideposts for a step-by-step approach to bicycle promotion that focused on integrating bicycling into everyday decision making in transport, traffic engineering, and urban development. This step-by-step approach successfully garnered political, public, and administrative support over time. The downside of this incrementalist approach is that bike route networks in both cities still have many gaps because bikeway infrastructure was built when individual opportunities arose and not as part of an integrated network. Bicycle promotion in both cities used a combination of bikeway infrastructure and soft policy, including marketing measures. In both cities, the quality of newly installed bikeway infrastructure increased over time from simple bike lanes to protected bike lanes separating cyclists from traffic. In contrast to Washington, DC, Frankfurt has a longer history of car-restrictive policies and overall has been more strict in limiting car use.

Keywords: bicycling; Frankfurt; Washington, DC; car-dependence; planning; sustainable transport

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1. Introduction

Many cities that intend to promote bicycling have a transport system and planning tradition that has been centered on the automobile, with little or no recent history of bicycling as a mode of transport. Lessons on increasing bicycling from leading bicycling-friendly cities such as Amsterdam or Copenhagen may not be fully applicable because those bike-friendly cities can rely on a tradition of bicycling and a history of building bikeway infrastructure that emerged over decades [1]. This paper compares successful bicycling promotion in Washington, DC and Frankfurt am Main, Hesse, Germany (from now on simply Frankfurt) over the last 30 years. Both are wealthy cities without a history of bicycling as a mode of transport prior to their efforts of bicycle promotion over the last decades. Instead, during the 20th century, both cities adapted their transport systems to the automobile. In recent decades, both cities have increasingly promoted bicycling starting in the early 1990s in Frankfurt and in the early 2000s in Washington, DC. Bicycling levels increased in both cities during this period. In Washington, DC, the share of trips made by bicycle increased fivefold from about 1% in the late 1990s to 5% in 2018. Frankfurt's share of trips by bicycle more than tripled from about 6% in the late 1990s to 20% in 2018 [2,3]. The goal of this article is to identify lessons for bicycle promotion from both cities by comparing histories, timelines, strategies, and bicycle-friendly measures implemented. The paper explores best practices in fostering bike planning in cities without a prior focus on planning for bicycles.

2. Materials and Methods

We collected data and information about bicycling trends, policies, plans, and programs in Washington, DC and Frankfurt from publicly available reports, plans, and documents; published academic and popular press books and articles; unpublished information and planning documents made available upon request by planners in Frankfurt and Washington, DC; and interviews with select current and former bicycle planners in both cities. In order to collect similar information for both cities, the research team established lists of criteria for data and information collection for both cities. This included general sociodemographic information, data on transport indicators, and detailed data and information on bicycling. We then searched the internet using Google and Google Scholar, as well as academic databases (Web of Science and Scopus), for information on bicycling in Washington, DC and Frankfurt. Search terms included the city names and "bicycling," "bicycle," "planning," and "policy." We also extensively searched the official planning and transport planning websites for both cities. For missing and additional information, we contacted general transport planners, bicycle planners, city planners, and regional planners in each city either listed as points of contact for bicycling issues on the cities' websites or as authors in reports or planning documents for each city. We also reached out to academics in transport planning and geography in the Frankfurt region to obtain leads for data sources and contacts.

We supplemented the information we collected through our search and email exchanges with four interviews with key bicycle planners and experts in both cities. Interviews lasted 60 to 90 min and were conducted via Zoom in English and German. Prior to the interview, we emailed candidate questions to the interviewees to facilitate the conversation. We kept detailed notes during the interviews. After the interviews, we summarized the conversations by topic. Follow-up questions were asked if necessary after the interview by email. In the text, we cite the interviewees as sources of information that was directly obtained during the interviews and not available in other documents. Details about names of interviewees and dates of interviews are part of the listing of references at the end of this paper. A comparison of the interview notes showed that, in general, interviewees reported similar information. In rare cases of conflicting narratives, we asked clarifying questions. For Washington, DC, we were also granted access to the raw data for the three most recent regional travel surveys. Access to these data allowed us to replicate statistics available in published reports for Frankfurt (where we did not obtain access to raw data for the travel surveys).

3. Results

3.1. Brief Overview of Geographic, Demographic and Socioeconomic Parameters of Washington, DC and Frankfurt (City and Metro Area)

Frankfurt and Washington, DC have roughly similar population sizes, but because of Washington's smaller geographic size, population density is a third higher there (see Table 1). Both cities experienced comparable strong population growth (+14%) during the last decade. Both are wealthy cities with high median household incomes and a high rate of population turnover moving in and out of the city every year. While Frankfurt is Germany's and one of Europe's centers of finance, Washington, DC is the seat of the US government. Both cities are the economic and employment centers of large metropolitan regions with 5.7 million inhabitants in the Washington, DC region and 2.4 million inhabitants in the immediate and 5.8 million inhabitants in the larger Frankfurt region. Large populations outside of Washington, DC and Frankfurt result in high numbers of daily commuters to the city from neighboring jurisdictions: about 550,000 daily in-commuters to Washington, DC and roughly 400,000 to Frankfurt. Compared to other North American cities, Washington, DC lacks skyscrapers and is often described as having a European-style urban design. Conversely, because of its skyscrapers, Frankfurt is often described as the most American-style city in Germany.

Table 1. Overview of demographics, geography, and transport indicators for Frankfurt and Washington, DC, 2020.

	Frankfurt	Washington (DC)
Population (in 1000)	765	705
Population growth 2010 to 2020 (%)	13%	14%
Land area (square kilometers)	250	177
Population density (per square kilometer)	3000	4000
Median HH income (in $US using PPP)	79,000	85,000
Car ownership per capita	470	510
Average trip distance (km, all modes)	6	6
Average trip duration (minutes, all modes)	21	24
Share of all trips (2018, residents only)		
Car	33	45
Public transport	21	16
Foot	26	29
Bicycle	20	5

In terms of transport indicators, Frankfurt has a lower car ownership rate per 1000 population (470 vs. 510) [4]. Average trip distances (6 km) and trip duration (21–24 min) are comparable in both cities. Frankfurt residents drive for a lower share of trips compared to Washington, DC residents (33 vs. 45%) and more likely ride public transport (21 vs. 16% of trips). Residents of both cities are roughly similarly likely to walk (26 vs. 29% of trips), but residents of Frankfurt are much more likely to ride a bicycle (20 vs. 5% of trips).

In recent decades, the share of trips made by bicycle increased in both cities. In Washington, DC, the share of trips made by bicycle increased fivefold from about 1% in the late 1990s to 5% in 2018 (see Figure 1). Frankfurt's share of trips by bicycle more than tripled from about 6% in the late 1990s to 20% in 2018 (see Figure 1). Increases in cycling between 2000 and 2018 are also confirmed in counts of bicyclists for each city: +320% at bridges crossing the Potomac and Anacostia rivers in Washington, DC and +250% for counts at the inner cordon (including bridges crossing the main river) in Frankfurt [5,6].

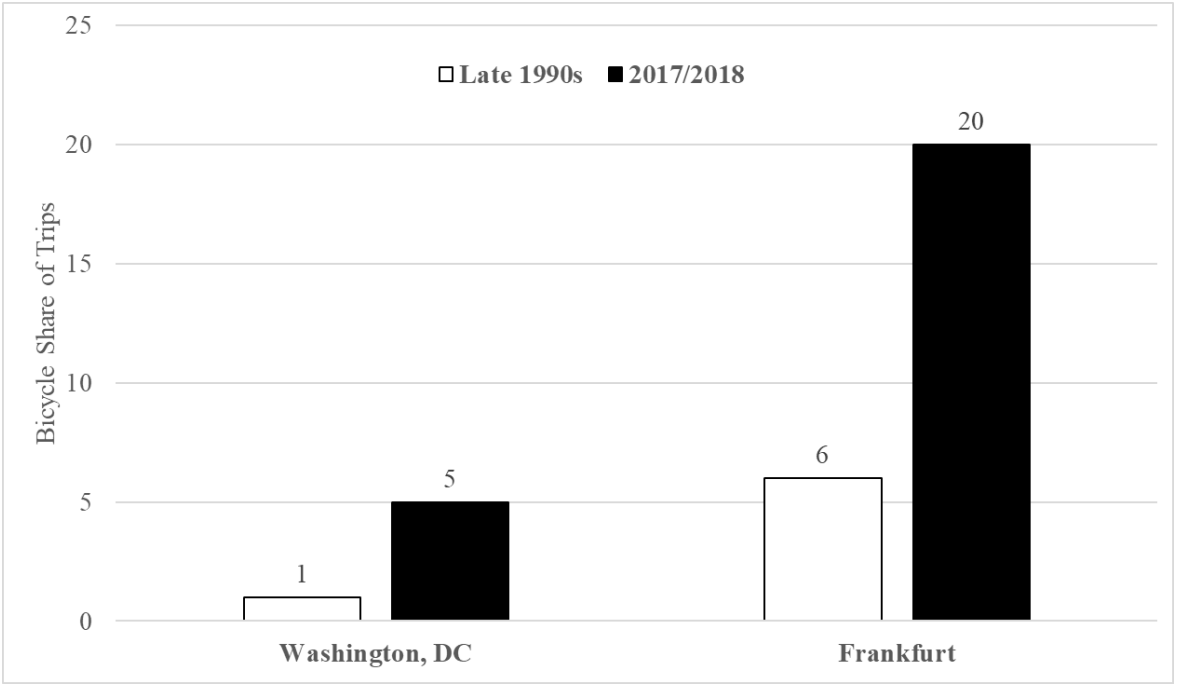

Figure 1. Trend in bicycle share of trips in Washington, DC and Frankfurt, Germany, between the late 1990s and 2017/2018. *Note: The graph shows the share of trips by bicycle made by residents of each city. Source:* [2,3].

In both cities, bicycling accounts for a higher share of trips for shorter trip distances: for example, 25% (Frankfurt) and 16% (DC) of trips between 3 and 5 km are by bicycle. Smaller but increasing shares of work commuters residing in surrounding jurisdictions are also riding their bikes to reach employment in Frankfurt and Washington, DC: 5% and 2% of out-of-town work commuters in 2018 arrived by bicycle [2,3].

3.2. Dominance of the Car in Transport Planning and System Prior to 1990

Like many German cities, Frankfurt was partly destroyed during WWII and rebuilt to accommodate the automobile with wide roadways and ample car parking. Moreover, the city abandoned many trolley lines to free up space for cars [7]. In the 1960s Frankfurt city council decided to build a subway system with the intent to remove more trolleys from city streets [8]. In the face of increasing awareness of the negative impacts of the automobile and citizen protests in the 1970s, Frankfurt started experimenting with and finally implementing some car-free pedestrian-only areas in the city and neighborhood centers [7]. However, cycling was not allowed in these zones [9]. During the 1970s and early 1980s, Frankfurt built (narrow) bike lanes on sidewalks, next to pedestrian walkways, often with the goal of allowing children to cycle to school. Besides the lack of connectivity to trip origins and destinations for the general population, the main drawbacks included missing curb cuts and poor visibility for motorists at intersections [9].

Like Frankfurt, transport planning in Washington, DC prioritized car travel in the post-WWII years [10]. This included road widening, building urban highways, providing ample car parking, and entirely abandoning the city's trolley system by 1962. Slightly later than Frankfurt, Washington, DC's regional subway system was planned in the 1960s and the first line opened in the mid 1970s [10]. Partly in response to the energy crises, in the early 1970s, bicycling experienced a boom in the USA. Washington, DC's bicycling advocacy and planning have their roots in that time [11]. Similar to other local and regional jurisdictions in the area, Washington, DC published its first bicycle plan in the late 1970s [12]. However, only a small part of the plan was implemented at the time. Most progress was made in building regional trail networks shared by pedestrians and cyclists, often on federally owned park land [13].

3.3. A Push to Promote Bicycling in Frankfurt and Neglect in Washington, DC in the 1990s

In the early 1990s, the fate of bicycling in Washington, DC and Frankfurt diverged. In Washington, DC, the position of a bicycle planner was discontinued partly due to large cuts to the city's budget in the face of a financial crisis [11]. Without a dedicated bike planner in Washington, DC, most progress was on the regional level. Bicycling became part of the regional long-range transport plan in 1991, and in 1998, a regional vision for bicycling was published [11]. Indeed, as in the 1980s, the regional network of off-street trails and shared-use paths expanded by building new trails along newly constructed highways and on federal park land [14]. Several of these new trails connected to Washington, DC. Bicycle commuting in Washington, DC increased from 0.8 to 1.2% of regular commuters during the 1990s [12].

In Frankfurt, the early 1990s saw several major changes in bicycle promotion. The main impetus was a change in city government with a coalition of Social Democrats and the Green Party winning Frankfurt's local elections in 1989 [9]. Among other initiatives, the new coalition government implemented traffic calming in most neighborhoods, reduced car parking availability in the city center, and promoted the possibility for developers to buy out of minimum car parking requirements in close proximity to public transport (with revenues used for public transport and bicycling projects). Moreover, in 1991, Frankfurt was the first among large German cities to create the position of a city bicycle coordinator [15]. Even though just one person, the position meant there was now a dedicated voice for bicycling within the city administration [9].

Several policies implemented by the new office helped to facilitate bicycling. First, cyclists were allowed to ride through car-free pedestrian zones. Previously, cyclists had to

dismount in those zones. The goal was to enable connectivity of cycling routes through pedestrian zones [9].

Second, a key strategy for bicycling promotion included opening one-way streets in traffic-calmed residential areas for two-way bicycle traffic. In the 1990s, Frankfurt traffic-calmed most of its residential streets to 30 km/h (~19 mph) [9]. In order to keep motorized through-traffic out of these neighborhood streets, the city implemented many one-way streets, often with alternating directions by city block to discourage motorized traffic cutting through neighborhoods [16]. Between 1993 and 1996, Frankfurt (along with some other German cities) participated in a trial project opening one-way streets in traffic-calmed areas for bicycle traffic. There were no alterations to the roadway, simply a sign allowing cyclists to ride in both directions along the one-way street. The trials successfully showed increased cycling levels (+20%) with no increase in crashes [17].

Third, plans were made for bike routes to connect the city's neighborhoods to the city center [9]. Those routes were to comprise traffic-calmed neighborhood streets, on-street bike lanes on major roadways, and intersections with bicycle traffic signals when crossing major roadways [18]. These routes were a significant change in Frankfurt's bike planning, which had previously been oriented towards bikeways on sidewalks facilitating children's commutes to schools [9]. The new network focused on all trip purposes and advocated for bike lanes on roadways to increase the visibility of cyclists at intersections.

During the early 1990s, the city also opened its first bicycle street where motorists are allowed to enter but have to yield to cyclists who are allowed to use the entire width of the street [15]. Moreover, the city installed bicycle parking at public transport stops, sometimes working with a local advertising company who would pay for the cost of the new covered bike parking for roughly 80 bikes and in return could use the walls of the bike parking sheds for advertisement [9]. Similar to the trail network in Washington, DC, during the 1990s, Frankfurt completed bicycle paths in the city's greenbelt, allowing cyclists to circle the city on a 75 km loop of shared-use paths [9].

Despite all the progress for bicycling in Frankfurt, when the conservatives took over city government in 1995, the position of bike planner was eliminated. Most large-scale bike projects were discontinued or never started, including many planned bike routes [18]. Thus, in the latter part of the 1990s, neither Washington, DC nor Frankfurt had a position dedicated to bike planning.

3.4. Crucial Transitions towards Successful Bicycling Promotion in the 2000s

In the early 2000s, Frankfurt's then 20-year-old general transport plan was updated. The new plan had the overall goal to reduce car use in the city [17]. It was also Frankfurt's first transport master plan to include bicycling as a mode of transport. Most political parties supported bicycling for various reasons, including worsening traffic congestion and the popularity of and guidance from a newly published federal bicycle transport policy [18]. Frankfurt's conservative party was also intrigued by the fact that a conservative lead government in the German city of Munster had helped transform that city to become the most bike friendly in Germany [18]. In 2005, just when the plan was finished, the Green Party and the Conservatives formed their first coalition government in Frankfurt. A Green party politician became head of transport in the city, and the government adopted the transport plan's most bike-friendly scenario of increasing cycling to 15% of trips by 2015 [16,18]. The scenario identified six groups of main measures for bicycle promotion: marketing, bikeway network design and planning, integration with public transport, bike parking, and signage. These areas were further subdivided into 61 specific task areas to promote bicycling [19]. The plan also identified user groups for different bicycling facilities, distinguishing the (infrastructure) needs of children, older adults, commuters, women, and the population at large [17].

The new coalition government in Frankfurt reorganized bicycle planning. Instead of having one bike planner, the city created a bicycle office, and in 2009, with four employees, it was officially opened. The new bicycle office was closely connected to transport planning,

traffic engineering, and traffic enforcement. This facilitated coordination and information exchange for planning, engineering, and implementation of bicycle projects [18,20]. Bicycle planners established personal and professional relationships with other city departments, facilitating the consideration of bicycling as a mode of transport in transport and urban development projects. The city continued its 1990s policy to open one-way streets in traffic-calmed areas for cyclists riding in both directions, opening more than 90% of one-way streets for two-way bicycle traffic by 2012 [19,21]. In 2005, an initial decision was made not to focus on completing the early 1990s plans for a large bikeway network, of which only a small portion had been built [18]. Design standards for the 1991 plans had become outdated, the proposed interventions to the streetscape were deemed too costly, and planning and implementation processes for such large-scale street alterations were seen as too time consuming [18].

Instead, the initial push to promote cycling aimed at including bicycling in daily transport engineering and planning decisions [18]: installing bike lanes or other bikeway infrastructure during roadway resurfacing, rehabilitation, or restructuring. The approach also comprised installing bike parking racks as part of many small transport projects throughout the city. The goal of this new approach was twofold. First, to increase awareness of bicycling issues throughout the city administration and change transport planners' and engineers' mindsets from seeing bicycling issues as a burden to actively accommodating bicycling as a routine task for every project [19]. Second, these minor improvements were designed to boost cycling as a convenient mode of transport [18]. Moreover, together with the region, the city increased outreach and communication about bicycling and solicited public input via roundtables [16,20].

In the 2000s, the city expanded bike parking at public transport stops and stations, installed bike parking racks throughout the city whenever possible (~500 to 1000 per year), and mandated bike parking in car parking garages [21]. In addition, bike-sharing systems were initially launched and later expanded in Frankfurt during the 2000s, starting with German Railways' (DB) Call-a-Bike system in 2003, followed by other private bikeshare companies later in the decade [16]. By 2012, 15% of all trips in the city were taken by bicycle. Thus, the city achieved its mode share goal 3 years ahead of schedule [21].

In 2001, as part of a new city government intending to increase livability, Washington, DC hired a full-time bicycle planner, giving bicycle planning new impetus. At the time, Washington, DC only had 3.2 miles of bike lanes, far from the 17 miles called for in the city's 1978 plan [11]. Initially, besides expanding bikeway infrastructure, the main task was developing the bicycling master plan, published in 2005. The plan, developed with citizen input, had three main goals, accompanied by 14 recommendations: building more and better bicycle facilities, developing and implementing more bike-friendly policies, and increasing bicycle-related education, promotion, and enforcement. The plan also called for increasing the share of commuters regularly cycling to work to 3% in 2010 and 5% in 2015 while decreasing the bicycle crash rate [12].

For bikeway facilities, the goal was to develop a bikeway network along arterial routes to place all district residents within 1/2 mile (0.8 km) of a bikeway facility and develop bikeway connectivity between neighborhoods, downtown, parks, schools, transit, and adjacent jurisdictions. This included 45 miles of new bike lanes, bikeway facilities on bridges, and new trails. The District Department of Transportation (DDOT) intended to use Bicycle Level of Service (BLoS), a quantitative measure of perceived safety and comfort, to identify roadways for improvements, with the goal to improve overall BLoS and eliminate roadways with very low BLoS (lower than letter grade D) [12].

The plan also called for 2000 new bike racks in DC by 2015, a bike parking garage at Union Station, and more bicycle parking in car parking garages, office buildings, and private residences. The plan envisioned improved data collection about bicycles and bicyclists to support informed decision making. Outreach programs were to target people of all ages, cyclists, and motorists, as well as in-school education [12]. Similar to Frankfurt, the bicycle planner coordinated with other transport and planning agencies in the city to

include bicycling in everyday planning, engineering, repaving, roadway restoration, urban development, and general transport decision making [22].

By 2010, Washington, DC had implemented several measures outlined in the master plan [23]. In 2008, Washington, DC's Smart Bike was the first docked bike-sharing program in North America, with 10 hard-wired docking stations and 120 bicycles placed throughout the city. In 2009, the city's first bike parking garage for 138 bicycles was opened just outside of Union Station, a commuter hub for subway, regional, and long-distance rail service [23]. By 2010, Washington, DC had built 60 miles of on-street bike lanes, a twentyfold increase compared to 2001 [23]. Many bike lanes were installed on roadways that previously had extra wide car travel lanes or parking lanes with excess width. The city focused its new bike lanes in the Central Business District and neighborhoods, such as Capitol Hill, Mount Pleasant, Adams Morgan, and U-Street that had some of the city's highest cycling levels in the early 2000s [11]. In addition, Washington, DC built ten additional miles of shared-use trails, installed over 2000 bike racks (including 11 bike corrals), required bike parking in parking garages, newly constructed multiunit residential and commercial buildings, and improved bicycling access to numerous bridges [23].

During the same time, the city also installed its first bicycle traffic signal, its first contraflow bike lane on a one-way street, bike boxes at several intersections, and the first 2.5 miles of protected cycle tracks separating cyclists from vehicular traffic with bollards and extra space [23]. DDOT collaborated with schools to include bicycling into the curriculum. Traffic enforcement for parking in bike lanes was increased [22].

Starting in 2006, Washington, DC has used federal funding to promote bicycling via a public outreach program called goDCgo. The program expanded transport demand management measures to highlight bicycling as a possible substitution mode for driving [22]. The program has included radio ads, advertisement, bike maps, and increasingly social media. An important element was employer outreach and events to encourage more bike commuting with large employers in the Washington, DC area [24]. By the end of 2010, Washington, DC achieved its goal of 3% of residents regularly cycling to work [23].

3.5. Growth in Bicycling and Bicycle Promotion in the 2010s

In both cities bicycling policy and promotion accelerated during the 2010s, building on the foundations laid in the first decade of the millennium. Between 2010 and 2019, Washington, DC built an additional 30 miles of bike lanes (up from 60 miles in 2010) (see Figure 2), increased the supply of protected bike lanes almost eight fold (16.6 miles up from 2.5 miles in 2010), installed 5 miles of contraflow bike lanes in one-way streets for motorized traffic, marked 20.6 miles of sharrows, expanded the shared-use trail network, installed a total of 20 intersections with bike signals (up from 1 in the late 2000s), and built 400 bike racks for bike parking per year [23]. The share of major arterial or collector roadways with a Bicycle Level of Service (BloS) lower than grade D decreased from over 20% to about 10%. Bike sharing also grew considerably [23]. In 2010, DDOT built a bike lane in the center of Pennsylvania Avenue between the U.S. Capitol and the White House—the nation's "main street" (see Figure 3). In September 2010, SmartBike was replaced with Capital Bikeshare (CaBi), jointly operated with neighboring Arlington County (and later other jurisdictions). In contrast to SmartBike, CaBi used solar panels for power and did not require costly hard-wired connections to the electricity grid. The initial phase of 100 CaBi docking stations was installed by February 2011. By 2018, the system included over 4500 bicycles and over 500 docking stations regionally (in 6 jurisdictions), recording 3.5 million trips per year [25].

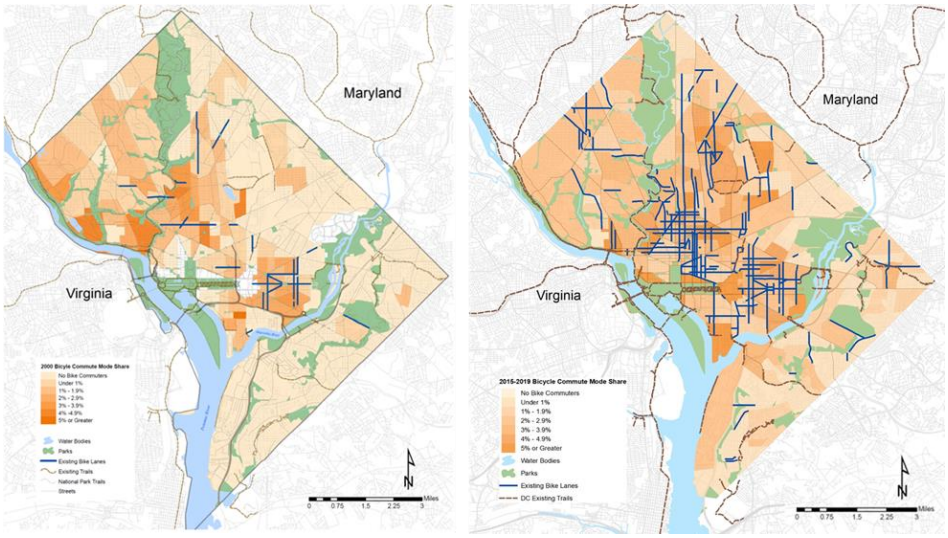

Figure 2. Bicycle commuting levels in Washington, DC (light brown to red background colors) and supply of bikeways on roads (blue lines) and shared-use trails (brown lines), 2000 (**left**) vs. 2019 (**right**). (Maps created for the authors by Dan Sonenklar (2000 map) and Brian Shelton (2019 map)).

Figure 3. Cyclists on bike lanes on Pennsylvania Avenue in Washington, DC, connecting the U.S. Capitol to the White House (Photo: Ralph Buehler).

In 2014, Washington, DC published its transport master plan called MoveDC. MoveDC's "bicycle element" called for increasing bicycling while making it safer [23]. Primary approaches included expanding and improving bicycle facilities, more bicycle-friendly policies, and more bicycle-related education, promotion, and enforcement. In addition, the plan includes details for creating a complete bicycle network comprising 136 miles of bike lanes, 72 miles of protected bike lanes, and 135 miles of trails built by 2030. MoveDC postulates that bicycle facilities should be improved and maintained whenever appropri-

ate, as streets or sidewalks are repaved or reconstructed. According to the plan, bicycle projects should incorporate actuated bicycle signalization and special bicycle signals at key locations. Moreover, MoveDC calls for more bridge improvements for bicyclists and further increases to BLoS. Overall, according to the plan, the bikeway network should have better connectivity, better maintenance, improved safety, and better parking. The plan also called for a review of all projects to ensure that they provide bicycle accommodation [23].

In 2015, Washington, DC adopted a Vision 0 policy with the goal to make walking and cycling safer and to eliminate pedestrian and cyclist traffic fatalities by 2024 [26]. The policy focuses on three main concerns, speeding drivers, distracted drivers, and enforcing traffic signals and stop signs. The Vision 0 policy codified DDOT's 2010 complete street's policy into law and moved it from an internal DDOT goal to one that is to be reflected in urban design, comprehensive and small area plans. As part of Vision 0 Washington, DC reduced speed limits to 20 mph on neighborhood streets in 2020 [22], similar to a policy implemented in Frankfurt during the 1990s. Washington, DC also requires bicycle training in second grade at all schools. Moreover, Washington, DC funds adult and youth education programs through Washington Area Bicyclists Association (WABA) [26].

Since 2010, bicyclist fatality data in Washington, DC show an upward trend, with about 1.3 cyclist fatalities per year in 2011–2013 and 2.0 cyclist fatalities per year in 2018–2020. Compared to the strong increase in cycling in Washington, DC (from 1.6% to 5.3% of all trips and from 9200 to 16,700 regular daily bike commuters), cyclist fatalities per trip decreased by 15% since 2010. This effect of safety in numbers is found in many jurisdictions: as cycling levels increase, bicycling gets safer per bicycle trip or kilometer cycled [27]. Longer-term trends indicate a decrease of about 70% of cyclist fatalities per bike trip since 2000. Thus, the rate of improvement of cyclist safety per trip has slowed in Washington, DC between 2010 and 2019 compared to the earlier decade. This still outperformed national U.S. trends with worsening cyclist safety between 2009 and 2018 [28].

Integration of bicycling with public transport also intensified with additional bike parking provided by the metrorail authority at its stations across the region, bike parking, bike lockers, bike cages at metrorail stops, and bicycle parking and lockers at park and ride locations [22]. Mimicking some of the policies implemented in Frankfurt since the 1980s, there has also been a trend in Washington, DC to experiment with small pedestrianized car-free areas, such as at The Wharf, temporarily at the Black Lives Matter Plaza, or with parklets and roadway closures which became popular during the COVID-19 pandemic. Last, Washington, DC has also increasingly dedicated separate bus-only lanes as bus and bike lanes, opening them for cyclists to use [22].

Overall, policies implemented to increase bicycling have been successful. After strong increases in cycling in the 2000s, bicycling in Washington, DC continued to grow, reaching 5.3% of all trips and 7.6% of all commutes, according to the latest travel survey.

In 2012, Frankfurt reached its goal of 15% mode share of bicycling (three years ahead of schedule). In the 2010s, Frankfurt continued implementing measures to promote bicycling as described in the 2005 transport plan. As in the 2000s, the process was still marked by small, incremental changes and a focus on "soft" measures (vs. large and costly infrastructure changes) [19]. For example, in 2010 the city installed a reporting scheme where cyclists (and all residents) could alert the city to safety, infrastructure, and other (small) bicycling-related issues that the city could then address to improve cycling, collecting over 1300 responses in the first decade [18]. Between 2012 and 2020, the city installed around 100 bicycle service stations throughout the city, where bicyclists can access tools for bike repair and inflate tires for free. In 2016, Frankfurt opened its first bike parking garage for 420 bicycles at the main train station. Costs are Euro 1 per day, 10 per month, and 100 per year. The location is ideal for commuters who arrive in or leave Frankfurt by train. The parking garage provides secure and protected parking and includes video surveillance and a bicycle repair shop [29].

Based on Frankfurt's Bike + Ride policy from 2005, the city expanded bicycle parking at public transport stops [29]. The policy outlines geographic priorities in expanding bicycle

parking and defines minimum specifications for the quality of bike parking. Besides parking at public transport stops and stations, the city also expanded bike parking at locations with high demand for bicycle parking, such as shopping centers, markets, or movie theaters. Between 2005 and 2015, the city increased the number of covered bike parking spots from 600 to 1000. After the Bike + Ride policy was updated in 2016, the city added another 1000 bike parking spots to reach a total of 2000 by 2020 [19]. Bike parking was also expanded at several regional rail stops, such as at the Rödelheim (from 92 to 208 bike parking spots) or Höchst (80 to 156) stations. The new bike parking stations often have two stories to be more space efficient. In addition, the city installs about 500 simple bike parking U-racks per year, sometimes including bike parking corrals where car parking spots are removed in lieu of bicycle parking [18]. Bike parking racks are also used at intersections to inhibit drivers from parking too close to intersections and hinder sight lines for drivers, pedestrians, and cyclists [18]. Moreover, bike parking is required for new office buildings and multi-unit residential buildings [29].

Compared to the 2000s, throughout the 2010s all political parties have agreed to promote bicycling. On average the city spent EUR 3.5 million on bicycling per year. In addition to the smaller measures described above, the city built bikeway infrastructure as part of general roadway construction, repair, and maintenance. the bikeway network still has many gaps and many narrow bikeways (see for example Figure 4), butthe city government aims to close these gaps and improve the existing bikeway infrastructure (18, 19).

Figure 4. Cyclists on a separated bike lane on the Untermainbrücke crossing the Main River leaving downtown with its skyscrapers (Photo: Ralph Buehler).

Like in Washington, DC, cyclist fatalities increased in Frankfurt between 2010–2012 and 2017–2019 (from 2 per year to 3.25 per year (or 2.6 without the 2018 negative outlier year)). However, adjusting for cycling levels, increasing from 13% of trips to 20% of trips and a doubling of bike trips per day, the cyclist fatality rate per bike trip fell by 43% and cycling safety improved. Longer-term trends since 2000 indicate a 60% decrease in the cyclist fatality rate per bike trip since 2000 [18].

Overall, bicycling promotion in Frankfurt until 2019 had been successful, reaching 20% of all trips. The city has designated almost 1400 km of bicycle routes in the city, including cycling on roadways and separate cycling infrastructure. The city has opened over 90% of all one-way streets for two-directional bicycle traffic. Moreover, the city already has traffic calmed 52% of all its roadways to 30 km/h or less and has strictly reduced automobile parking in the city center [19].

The year 2019 was a significant turning point for cycling in Frankfurt. The three governing parties of the city agreed on a new bicycle policy called *Fahrradstadt Frankfurt* (Bicycle City Frankfurt) [30]. This was in response to a grass-roots bicycling initiative that collected more than 40,000 signatures to pressure the city government to promote bicycling. The main component of the new plan is to install 45 km of new separated bike lanes by 2023. The protected bike lanes are to be a minimum of 2.30 m (7.5 feet) wide and physically separated from motorized traffic. In addition, 15 major intersections are to be redesigned by 2022 to better accommodate cyclists through infrastructure measures and signal timing. The city intends to connect express bikeways from the hinterlands through the city, allowing direct, fast, and safe cycling routes. In addition, each year, the city will design 5 to 10 km of neighborhood streets to prioritize bicycle traffic through bicycle priority streets and restrictions of motor vehicle access. Car-restrictive measures are going to be explicitly part of considerations in all roadway and intersection redesigns. Moreover, the city is to install 2000 new bike parking spaces per year, and 4000 new bike parking spots were installed in 2020 alone. The city will also fund 18 new additional full-time equivalent positions in the city administration for five years in a working group called 'Bicycle Friendly City.' The years 2020 and 2021 saw EUR 20 million in additional funding for bicycle projects [29].

4. Discussion

Both Frankfurt and Washington, DC have successfully promoted bicycling despite their history of being car-oriented cities. As of 2020, cycling levels in both cities compared favorably with other cities in their respective countries (see Figure 5). In the U.S., Washington, DC's bicycle commute mode share of roughly 5% is much higher than in Miami (1%), Atlanta (1%), Boston (2%), or Denver (2%) and comparable with San Francisco (4%), Minneapolis (4%), and Portland, OR (7%) but much lower than in smaller bike-friendly cities such as Davis, CA (19%) and Boulder, CO (12% [30]). Frankfurt's bicycle mode share of 20% compared favorably with 6% in Dortmund, 8% in Stuttgart, 12% in Cologne, and 18% in Berlin and Munich but was much lower than in the bike-friendly cities of Bremen (27%) and Karlsruhe (35%) [31]. Cycling levels in both cities are much lower than in European cities with a history of planning for bicycles such as Copenhagen (29%) or Amsterdam (36%). These cities have implemented bicycle-friendly measures for a longer period of time and to a much greater extent than Frankfurt or Washington, DC [1,32–34]. In some ways, the increase in cycling in Frankfurt and Washington, DC is comparable to the success of bicycle promotion in Seville, Spain, another city without a history of bicycling [35]. However, compared to Frankfurt and Washington, DC, Seville's success occurred during a shorter period of time. In Seville, the number of trips by bicycle increased six-fold between 2006 and 2012. In contrast to Frankfurt and Washington, DC where political support for cycling was more limited, cycling in Seville enjoyed strong government support, building an entire network of separated cycle tracks in a short period of time [36].

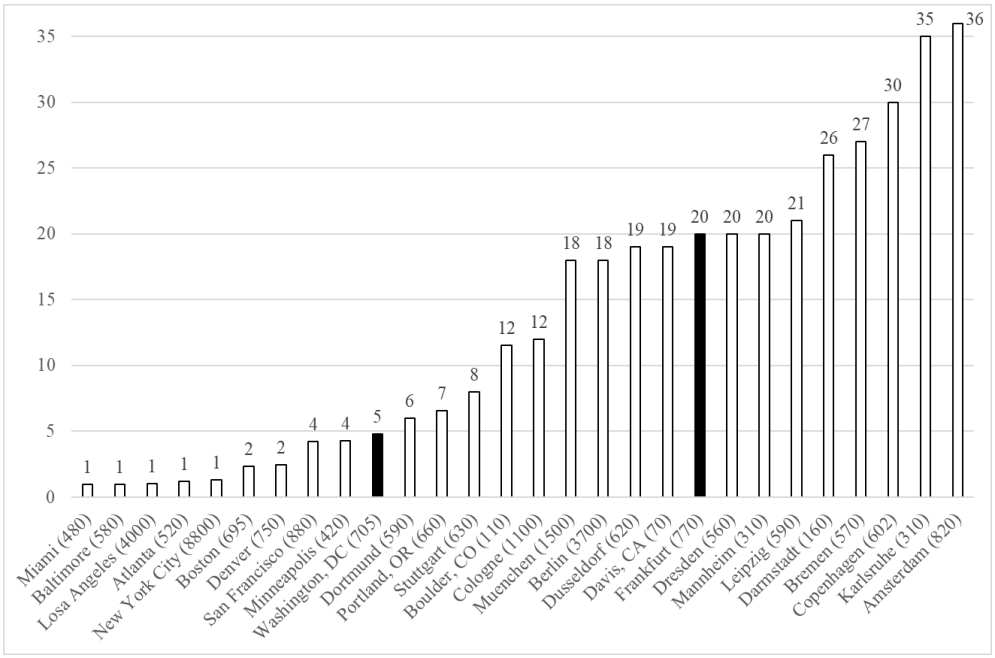

Figure 5. Percent of trips made by bicycle in U.S. cities, German cities, Copenhagen, and Amsterdam, 2017–2019. *Note: Data for US cities are for the commute to work only. Population size of the city in parenthesis. Sources:* [30,31].

In Frankfurt and Washington, DC, the current success in bicycle promotion has its roots in the early 2000s. Besides timing, there are also several similarities in planning approaches found in both cities.

First, both cities used a combination of hard infrastructure and soft policy and promotional measures. This is similar to other cities that successfully promoted bicycling using a mix of measures [34–36]. In terms of infrastructure, both cities expanded and improved the quality of bike parking, installed bike lanes, and more recently protected bike lanes and traffic-calmed neighborhood streets where cyclists can share the roadway with low levels and slow-moving motorized vehicles. Supporting these measures, and in many ways paving the way for implementing hard infrastructure measures, were soft measures, including marketing, public outreach, and cyclist training. This included bike maps, bike-to-work programs, coordination with employers to promote bike commuting and bike parking at work, opportunities for public input, and bicycle training in schools. Both cities improved the integration of bicycling with public transport through bicycle parking at public transport stops and stations and bike racks on buses in Washington, DC. Both cities also have bike-sharing programs that have been shown to attract different user demographics than regular cyclists.

Second, Frankfurt and Washington, DC both had detailed bike plans and mode share goals for bicycling, which has also been common in many other cities interested in bicycle promotion [1,35,36]. However, in Frankfurt and Washington, DC those plans were mainly used as guideposts for a slow and steady approach to bicycle promotion. In both cities, the focus was not on rigidly implementing large bikeway infrastructure projects prescribed by a master plan but on integrating bicycling into everyday decision making in transport, traffic engineering, and urban development. This process required building professional and personal relationships with planners and engineers throughout the city administration. Over time, these connections helped elevate the role of bicycling in the everyday activities of the city. Bicycling is now an integral aspect in the planning of the (re)development of new neighborhoods and other projects in both cities.

Moreover, these relationships helped bike planners identify opportunities for bicycling such as including bikeway facilities on new bridges. Combined, this approach slowly improved conditions for bicycling over time.

The gradual approach of bicycle promotion also helped garner political support. For example, by initially focusing on smaller and easier to implement bike measures and to avoid costly and controversial bikeway projects, bike planners improved cycling conditions and prevented political fights that could have alienated parts of the population. Later, with more cyclists in the city and greater political and popular support, bike planners could move towards more costly and politically more contentious projects.

Third, in both cities, while successful at increasing cycling, the gradual approach to bicycle promotion has resulted in splintered bikeway networks. Thus, on their daily routes, cyclists can only ride on bikeway infrastructure for parts of their trips. Still, they encounter missing bikeway links with either no or substandard bikeway infrastructure. This hampers bike promotion for large groups of society who have been shown only to consider riding if they do not have to share roadways or ride without protection in close proximity to fast-moving or high levels of motorized traffic [37]. In both cities, the quality of newly installed bikeway infrastructure improved over time. During the 2010s, the cities pivoted from building simple bike lanes along roadways with higher speeds and higher levels of motorized traffic to increasingly installing protected bike lanes that additionally separate cyclists from traffic.

Fourth, in contrast to Washington, DC, Frankfurt has a longer history of implementing stricter policies to discourage car use. For example, Frankfurt started reducing car parking in the city center and traffic calming residential neighborhoods as early as the 1990s. Washington has also reduced car parking, but later than Frankfurt. In addition, Washington, DC only reduced its general speed limit on residential streets to 20 mph in 2020, while Frankfurt started traffic calming its neighborhoods in the 1990s.

Last, in the coming years, both cities have similar goals in expanding their networks of protected bike lanes and improving cyclist safety, in particular at intersections. In Washington, DC, the equitable distribution of bike lanes across the city and encouraging all groups of society to cycle will also be a focus. Cycling in Frankfurt just received a boost with the city's new policy of making Frankfurt a bicycle city. Additional funding, staff, and political will to prioritize bicycling over other modes may help cycling to even higher levels.

5. Conclusions

Frankfurt and Washington, DC demonstrate that it is possible to promote cycling in cities without a history of bicycling. Both cities chose similar approaches to cycling promotion that can provide lessons for other car-oriented cities in North America and Europe.

First, as in many other cities, one key to bicycle promotion in Frankfurt and Washington, DC was a package of mutually supporting policies to promote cycling. This included hard infrastructure measures, such as bikeways and bicycle parking and public and employer-based outreach campaigns to promote cycling, and the integration of bicycling with public transport. At the same time, both cities implemented policies that made driving an automobile less attractive through slower speed limits, as well as less and more expensive car parking. This policy package can be mutually supportive. Improved bicycling conditions that make cycling a viable alternative to driving can make it easier to implement car-restrictive policies, while car-restrictive policies make cycling more attractive. Lower cycling levels in Washington, DC compared to Frankfurt are likely related to fewer car-restrictive measures implemented in Washington, DC.

Second, like most car-oriented cities, Frankfurt and Washington, DC did not have a history of planning for bicycling. In both cities, newly hired bike planners had to forge relationships with transport engineers and transport, land-use, and development planners to consider bicycling in everyday decision making and new large-scale infrastructure

projects. This process took time and required building trust and mutual understanding within city administrations. The case studies suggest that personal and professional relationships between bike planners and other planners and engineers within the city administration are crucial for promoting bicycling.

Third, including bicycling into everyday decision making helped improve cycling conditions incrementally over time and attract an increasing number of cyclists. With increasing cycling trips, it became politically easier to implement more expensive and more controversial bicycle infrastructure, such as removing automobile parking or car travel lanes and rededicating the space as bike lanes or protected bike lanes. In Frankfurt, over time, cyclists increased their political influence to push the city government to adopt a new goal to make Frankfurt a bicycle city, something that would have been unthinkable and not politically feasible in the 1990s.

Overall, both cities demonstrate that an incremental approach to bicycle promotion can be successful at improving conditions, as well as public and political support for cycling.

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