Daily Travel and CO_2 Emissions from Passenger Transport: A Comparison of Germany and the United States

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ABSTRACT

Federal, state, and local governments in the USA and Germany have the goal to reduce petroleum use and associated Greenhouse Gas (GHG) emissions from ground passenger transport. This article first compares trends of CO_2 emissions from passenger transport in Germany and the USA since 1990. Germany reduced CO_2 emissions from passenger transport at a faster rate than the USA—even controlling for population growth, economic activity, and travel demand. Moreover, for all indicators CO_2 emissions from transport were much higher in the USA than in Germany: 11.7 times greater for total CO_2 emissions, 3.1 times per capita, 2.1 times per passenger kilometer, and 2.4 times per unit of Gross Domestic Product (GDP). Next the paper compares US and German policies that can help decrease CO_2 emissions from passenger transport through improvements in technology including fuel economy and CO_2 tailpipe emission standards, vehicle registration fees and taxes, incentive programs for the purchase of fuel efficient cars, and biofuel standards. Lastly, the paper briefly highlights policies in Germany and the USA that shape the relative attractiveness of driving, public transport, walking, and cycling. The analysis concludes with policy lessons for both countries.

1. INTRODUCTION AND OVERVIEW

Federal, state, and local governments in the USA and Germany have the goal to reduce petroleum use and associated Greenhouse Gas (GHG) emissions from transport. In 2010, the transport sector was responsible for 20% of GHG emissions in Germany compared to 31% in the USA [1, 2]. In both countries the vast majority (~95%) of energy for transport came from petroleum and Carbon Dioxide (CO_2) accounted for about 95% of GHG emissions from transport [1, 2].

Automobiles, light trucks, and public transport were responsible for roughly two-thirds of transport GHG emissions in each country—accounting for 13.5% of total CO_2 emissions in Germany and 22.7% in the USA—[1, 2]. In 2010, annual per-capita CO_2 emissions from ground passenger transport in the USA were three times greater than in Germany: 3,800 vs.1,200kg [1, 2]. The difference for ground passenger transport between the two countries is larger than for annual per capita CO_2 emissions from fuel combustion for the countries as a whole (17,000 vs. 9,200kg) as well as for other sectors (electricity and heat: 7,100 USA vs. 3,800 Germany; industry: 2,600 USA vs. 1,500 Germany; residential: 1,000 USA vs. 1,400 Germany; other: 900 USA vs. 700 Germany). Even adjusting for economic activity, CO_2 emissions from passenger transport per unit of gross domestic product (GDP) were 2.4 times greater in the USA than in Germany.

Tackling emissions from ground passenger transport has proven difficult, because improvements in technological efficiency of cars and fuels can be off-set by heavier vehicles, more powerful engines, and longer travel distances (the so-called 'rebound effect') [3]. Compared to the energy and industry sectors, passenger transport emissions are more difficult to regulate, because travel behavior depends on individual decisions about residential location, vehicle ownership, transport mode choice, number of trips, and travel distance [4, 5].

This article first compares trends of CO_2 emissions from passenger transport in Germany and the USA since 1990. Statistics reported in this section refer to 'CO_2 equivalent' emissions—a measure that also accounts for other GHGs, such as CH_4 and N_20. Next the paper discusses policies that can help decrease CO_2 emissions from passenger transport through technology and changes in travel demand. The analysis concludes with policy lessons for both countries.

Many Similarities between Germany and the USA

Germany and the USA present many similarities that make a comparison of CO_2 emissions from transport and related policies meaningful [6]. Both are western democracies with market economies, a high standard of living, and federal systems of government in which the interaction between federal, state, and local governments shapes transport policies [6]. Both countries have large networks of limited access highways, a similar share of licensed drivers (70%) in the population, and an important automobile industry [7]. In both countries most suburban development occurred after WWII during periods of rapid motorization. In Germany and the USA the automobile is an important status symbol [8, 9]. Both countries have among the highest motorization rates in the world. However, compared to Germans, Americans own 30% more vehicles: 766 vs. 585 cars and light trucks per 1,000 inhabitants [10, 11].

2. Trend in CO_2 Emissions from Passenger Transport in Germany and the USA

Germany was more successful than the USA in reducing CO_2 emissions from passenger transport over the last two decades (see Table 1). Between 1990 and 2010, total ground passenger transport CO_2 emissions in Germany declined by 15% compared to a 12% increase in the USA. CO_2 emissions in the USA increased sharply between 1990 and 2005 (+21%) and then fell between 2005 and 2010. The drop in CO_2 emissions between 2005 and 2010 is likely related to the more severe economic crisis in the USA compared to Germany, higher volatility of fuel prices in America because of a lower share of taxes in the price of gasoline in the USA, and a decrease in driving in the USA. For example, the U.S. Department of Transportation [11] reports a sharp drop of 15% in passenger kilometers of car travel between 2006 and 2009. However, even in 2010, passenger transport CO_2 emissions in the USA were 11.7 times greater than in Germany—up from a ratio of 8.9 in 1990. This increase is partially explained by faster population growth in the USA than in Germany.

Adjusting for population size, per-capita CO_2 emissions increased in the USA between 1990 and 2005, but declined between 2005 and 2010—resulting in 9% lower CO_2 emissions per capita in 2010 compared to 1990. In Germany, per capita CO_2 emissions declined by 17% between 1990 and 2010. In 1990 emissions per capita were 2.8 times greater in the USA than in Germany. By 2010, this ratio had increased to 3.1—reflecting Germany's stronger decrease in CO_2 emission during that time frame.

Between 1990 and 2010, CO_2 emissions per kilometer traveled declined by 20% in Germany but only 3% in the USA—reflecting larger gains in vehicle fuel efficiency as well as increases in public transport use and cycling in Germany during this time. Compared to economic activity, measured in inflation-adjusted $ of constant GDP, between 1990 and 2010 Germany decreased its CO_2 emissions from passenger transport at a faster rate than the USA (-36% vs. -31%).

In summary, between 1990 and 2010 Germany reduced CO_2 emissions from passenger transport at a faster rate than the USA—even controlling for population growth, economic activity, and travel demand. Moreover, for all indicators CO_2 emissions from transport were much higher in the USA than in Germany: 11.7 times for total CO_2 emissions, 3.1 times per capita, 2.1 times per passenger kilometer, and 2.4 times per unit of GDP.

	1990	1995	2000	2005	2009/2010	*% Change 1990-2000*	*%Change 1990-2005*	*% Change 1990-2010*
Total CO_2 Equivalent (Tg)								
Germany	117	119	115	107	100	-2	-8	-15
USA	1,039	1,116	1,216	1,259	1,165	17	21	12
Ratio USA/Germany	*8.9*	*9.4*	*10.6*	*11.7*	*11.7*			
CO_2 Equivalent per Capita (Kg)								
Germany	1,470	1,455	1,399	1,303	1,217	-5	-11	-17
USA	4,166	4,246	4,309	4,255	3,793	3	2	-9
Ratio USA/Germany	*2.8*	*2.9*	*3.1*	*3.3*	*3.1*			
CO_2 Equivalent per Passenger km (G)								
Germany	134	121	119	113	107	-11	-16	-20
USA	214	228	217	214	208	1	0	-3
Ratio USA/Germany	*1.6*	*1.9*	*1.8*	*1.9*	*1.9*			
CO_2 Equivalent per Constant $1,000 GDP (using PPP) (Kg)								
Germany	57.0	52.4	46.2	41.8	36.4	-19	-27	-36
USA	129.4	122.7	108.4	99.7	89.0	-16	-23	-31
Ratio USA/Germany	*2.3*	*2.3*	*2.3*	*2.4*	*2.4*			

TABLE 1. Trend in CO_2 Emissions from Ground Passenger Transport in Germany and the USA, 1990-2010 *Sources: [1, 2, 12]. Note: CO_2 equivalent emissions are based on national fuel consumption estimates. The data do not capture 'gray imports' due to refueling abroad.*

2.1 Federal GHG Reduction Goals for Transport

Since ratifying the Kyoto Protocol Germany has set national targets for reducing GHG emissions. Between 1990 and 2010 Germany reduced its total GHG emissions by 22% and has the goal to achieve a 40% reduction relative to 1990 by 2020 [13]. Between 1990 and 2010, emissions from transport declined at a lower rate than those for industry and energy sectors. Achieving the overall 40% target by 2020, however, requires the transport sector to reduce its annual emissions by 20-25% between 2005 and 2020 [13].

There is no explicit federal policy to reduce GHGs in the USA. However, since 2009 the Environmental Protection Agency (EPA) has regulated GHG emissions as air pollutants that endanger public health and welfare [14]. Moreover, 23 States had GHG reduction targets and 37 States had climate action plans in 2012. GHG reduction targets vary by state. For example, California's target is to achieve 1990 emission levels by 2020 [15].

In both countries federal governments have developed a number of policies that directly or indirectly reduce CO_2 emissions from automobile transport including fuel economy and CO_2 tailpipe emission standards, vehicle registration fees and taxes, incentive programs for the purchase of fuel efficient cars, biofuel standards, and gasoline taxes. Federal governments also support local and state policies that can help change travel demand by promoting public transport, walking, and cycling, as well as land-use policies that keep trip distances short.

3. IMPROVED TECHNOLOGY

3.1 Fuel Efficiency and CO_2 Emission Standards

There are no fuel efficiency or CO_2 emission standards on the national level in Germany. But Germany is subject to EU regulations. Both, the EU and the USA attempt to reduce GHG emissions from transport through vehicle fuel efficiency and/or CO_2 emissions standards [14, 16]. The two standards are treated interchangeably here, because the burning of fossil fuels is closely related to CO_2 emissions. In 2010, the German automobile and light truck vehicle fleet was 55% more fuel efficient than the US light duty vehicle fleet (35 vs. 23 mpg or 7.5 vs. 11.2 l per 100km of travel). Fuel efficiency data presented in this paper rely on the International Council for Clean Transportation's (ICCT) conversion tool to allow comparison of the U.S. Corporate Average Fuel Economy (CAFE) and the New European Driving Cycle (NEDC) testing cycles. Miles per gallon (mpg) values presented in this paper are based on the U.S. CAFE testing cycle. Liters per 100 kilometers (l/100km) values are based on the NEDC.

In 1975 the USA implemented the world's first fuel economy standards for cars and light trucks called Corporate Average Fuel Efficiency (CAFE) standards [17]. Between 1980 and 1991, the fuel efficiency of the U.S. light duty vehicle fleet increased from 16mpg to 21mpg (17 to 13 l/100km). Progress has been slower since then, reaching a fleet average of 24mpg (11 l/100km) in 2009. Decreasing gains in fuel efficiency are partially explained by the failure to raise CAFE standards for new passenger cars for nearly two decades after reaching 27.5mpg (9.7 l/100km) in 1985. Moreover, CAFE set lower fuel economy standards (20.7mpg or 13.2 l/100km) for increasingly popular light trucks [18]. In the mid-1970s, when CAFE standards were developed, light trucks only accounted for a small share of the vehicle fleet and were mainly used by businesses or for agriculture. However, since then minivans, sport-utility vehicles (SUV), and pick-up trucks, all classified under CAFE as light trucks, became increasingly popular as private vehicles. For example, in 2002 new retail vehicle sales for light trucks surpassed those of passenger cars [18]. A greater share of light trucks with lower fuel economy depressed the overall fuel economy of the U.S. passenger vehicle fleet.

In response to the Energy Independence and Security Act (EISA) 2007 fuel economy standards were revised. The new standards apply to light duty vehicles—including both passenger cars and light trucks (< 8,500 pounds) [19, 20]. The standards vary by vehicle size and a formula based on vehicle size requires smaller vehicles to achieve higher fuel efficiency than larger vehicles. In the US system vehicle size is assessed as the product of track width and wheelbase (i.e. distance between wheels on the same axle and distance between the front and rear axles). Thus manufacturers of smaller cars face stricter standards and producers of larger cars are subject to comparatively less strict standards. New light duty vehicles are set to average 30mpg by 2015 and 39mpg by 2020 (8.8 l/100km by 2015 and 6.6 l/100km by 2020) [21].

Because of the close connection of fuel efficiency and CO_2 emissions, the new standards were developed in collaboration by NHTSA and EPA (as well as the State of California and major car manufacturers). In 2007, EPA gained the authority to regulate GHG emissions under the Clean Air Act *(Massachusetts v. EPA)* and determined that GHGs endanger public health and welfare [20]. The mpg standards for 2015 and 2020 translate to 181 and 144 g CO_2/km for new light duty vehicles (based on the NEDC).

Historically, there were no fuel efficiency standards on the national level in Germany. Higher fuel efficiency was mostly explained by higher taxes on fuel and resulting increased demand for more fuel efficient cars. However, in the late 1990s and early 2000s, car manufacturers entered into a voluntary agreement with the European Commission (EC) promising to reduce average CO_2 emissions of new vehicles to 140g CO_2/km over ten years [22]. There were no fines for not meeting the standard in the voluntary agreement, but there was the looming threat of EC regulation. In the years following the voluntary agreement most improvements in fuel efficiency in Germany were due to an increasing share of diesel vehicles in the vehicle fleet (a process termed *dieselization*). Diesel engines are more efficient than gasoline powered engines, but diesel fuel has higher energy and carbon contents per unit. Overall, improvements in reductions of CO_2 emissions under this voluntary agreement were considered insufficient reaching only 160g CO_2/km in 2006.

As a result, since 2009, German passenger cars have become subject to EU CO_2 emission standards requiring manufacturers to achieve an average of 130 g CO_2/km by 2015 and 95g CO_2/km (45.5 and 60.6 mpg) by 2020 [22, 23]. Specifics about the standards are still under negotiation, partly because Germany has pushed to delay the 95g CO_2/km goal from 2020 to 2024 [24]. Similar to the revised standards in the USA, EU standards will vary by vehicle size. In contrast to the USA, where vehicle size is determined by track width and wheelbase, the EU chose vehicle weight as a guide to distinguish between smaller/lighter and larger/heavier vehicles. The rate of differentiation between lighter and heavier vehicles, based on the slope of the so-called *linear limit value curve*, has been part of intense negotiations between producers of heavier cars (including many cars from Germany) and manufacturers of lighter cars. Manufacturers of heavier vehicles have argued for stricter standards for smaller vehicles and vice versa.

Under these rules, manufacturers have to achieve the required standard for all cars sold per year or face a fine of €5 (US $7) for each vehicle sold during the year for the first gram above the standard, €15 (US $20) for the second gram, €25 (US $38) for the third gram and €95 (US $124) for each additional gram. However, car manufacturers are allowed to join forces and have their vehicle fleets evaluated jointly. Thus, a manufacturer that fails to meet the standard could partner with a manufacturer that exceeds the standard. Jointly, both manufacturers could then meet the standard. Additionally, manufacturers can also gain credits for low emission vehicles with <50 g CO_2/km [16, 22]. The EU sets different goals for light commercial vehicles that account for about 12% of the European vehicle fleet and their target rate is 175 g CO_2/km by 2020 [16, 23].

Compared to the USA, proposed EU standards for 2015 (130 vs. 181g) and 2020 (95 vs. 144g) are more stringent for passenger cars and non-commercial light trucks combined. However, the USA proposes to further reduce CO_2 emissions per km to 107g by 2025 (based on NEDC). US goals for 2025 can be decomposed into standards for light trucks (137g) and passenger cars (93g). Thus, if Germany were successful in delaying the EU 2020 goals until 2024, U.S. standards for passenger cars in 2025 would be more stringent than standards in the EU (93 vs 95g) [24].

Both EU and U.S. CO_2 standards differentiate by vehicle size. The design of US standards possibly offers greater incentives to increase fuel efficiency. Under the EU standard producers of more fuel efficient and lighter vehicles are subject to stricter standards—even if the floor area of the car is the same as for a heavier vehicle. In the U.S. a lighter vehicle (with the same floor area) can help improve a manufacturers overall fuel efficiency/CO_2 emissions rating. Thus, the incentives to produce more fuel efficient larger vehicles (with large track width and wheel base) in the USA are greater than in the EU, where those cars become subject to tougher fuel economy standards.

3.2 Incentives to Lower Pollution from Cars

Governments in both countries provide incentives for less polluting cars and fuels. For example, in 2009, Germany changed its formula to calculate annual vehicle registration fees for new cars to include CO_2 emissions besides engine size and fuel type (Diesel/gasoline) of the vehicle. The CO_2 share of the annual registration fee is small and is calculated as €2 (US $ 2.60) for each gram of CO_2 emissions above a certain emissions threshold: 120g for cars built in 2009, 110g in 2012, and 95g in 2014. Electric vehicles are exempt from any annual registration fees for 5 years [25]. However, studies suggest that the CO_2 element of the registration fee is too small to significantly change customer preferences toward less polluting cars [25].

Vehicle registration fees in the USA vary by state and some local jurisdictions additionally assess annual personal property taxes [26]. However, the federal government has offered periodic tax incentives for the purchase of alternative fuel vehicles, certain cars with diesel engines, hybrids, plug in hybrids, and electric vehicles. Incentives and program structures vary, but can be as high as $7,500 in federal tax credits for electric vehicles and plug-in hybrids. In 2012, all but 12 states offered additional incentive programs for hybrid electric vehicles and plug-in hybrids [18].

During the economic crisis of 2008/2009, federal governments in Germany and the USA sought to support their automobile industries through monetary incentives for new car purchases if buyers turned-in their old vehicles (better known as 'Cash for Clunkers'). In both countries older less fuel efficient vehicles were replaced with more fuel efficient newer vehicles with lower CO_2 emissions per km. But the volume of new vehicle sales was too small to significantly reduce CO_2 emissions from passenger transport [27, 28].

By its design the U.S. program provided more incentives to increase fuel efficiency than the program in Germany. In 2009, Germany offered a €2,500 (US $3,300) incentive towards the purchase of a new car for individuals who scrapped vehicles that were a minimum of 9 years old. Even though the program was labeled as 'environmental allowance' (Umweltprämie) there was no requirement about fuel efficiency or CO_2 emission standards for the new cars. An analysis found that newly purchased cars averaged 20% lower CO_2 emissions per km than scrapped cars. Through this program 1.9 million individuals received a total of about €5 billion (US $7.5 billion) in subsidy [28].

In July 2009, the USA implemented a similar program, called 'Car Allowance Rebate System' (CARS), offering $3,500-$4,500 if buyers of a new car scrapped an old vehicle. In contrast to the German program that was only based on the age of scrapped vehicles, the U.S. program required old vehicles to have fuel economy lower than 18mpg and new cars to achieve at least 22mpg [27]. The exact subsidy amount increased with the differential in fuel efficiency between the scrapped car and the new vehicle. Average fuel efficiency of newly purchased vehicles was 58% greater than for scrapped cars (24.9 vs. 15.8mpg). Through this program 700,000 individuals received a total of about $3 billion in subsidy [27].

In both countries new vehicles purchased under these programs were more fuel efficient and had lower CO_2 emissions per km than the vehicles traded-in, but the volume of new vehicle sales under these programs was too small to significantly reduce CO_2 emissions from passenger transport [27, 28]. Moreover, critics argue that the programs may have resulted in negative environmental effects when considering the full life-cycle cost and not just on road-fuel economy of cars, as well as higher levels of use in newer cars (e.g. miles driven per year).

Both countries support the development of alternative fuels and alternative fuel vehicles including biodiesel, electricity, hydrogen, natural gas, and ethanol. The USA has a longer history of experimenting with and using alternative fuels [26]. For example, a 10% share of ethanol in gasoline (E-10) is common in the USA. By contrast in 2011, the German federal government experienced a public relations disaster and public resistance when attempting to increase the ethanol content of gasoline from 5% to 10%. Many Germans believed that E-10 would destroy their vehicles. Mirroring a media campaign by the car industry in Germany against E-10, American AAA issued a similar warning for new E-15 standards in the USA [29].

4. TRAVEL BEHAVIOR AND FEDERAL POLICIES

More CO_2 emissions from passenger transport in the USA can be partly explained by the lower fuel efficiency of the U.S. vehicle fleet discussed above. However, more trips by automobile and longer travel distances are important factors as well. The automobile accounts for a much higher share of trips in the USA than in Germany (86% vs. 58% of daily trips). By contrast, compared to Americans, Germans make a 4.5 times higher share of trips by public transport (9% vs. 2% of trips), are 10 times more likely to ride a bicycle (10% vs. 1% of trips), and 2.2 times more likely to walk (24% vs. 11% of trips) [30, 31].

A recent international comparison shows a correlation between CO_2 emissions from ground passenger transportation and the share of daily trips made by walking, cycling, and public transportation [32]. Compared to Western European countries, the USA has the highest annual CO_2 emissions from ground passenger transport per capita and the lowest share of trips by foot, bicycle, and public transport (3,800 kg, 14% of trips). CO_2 emissions are lower and the share of trips by walking, cycling, and public transport are higher in Western European countries, such as the Netherlands (1,000 kg, 51%), Austria (1,100 kg, 42%), Germany (1,200 kg, 43%), Denmark (1,200 kg, 41%), Norway (1,300 kg, 36%), or the UK (1,300 kg, 34%) [2, 32, 33]. There are no recent national travel surveys for all trip purposes for Australia and Canada. The only available travel data for those countries is the share of trips by walking, cycling, and public transport for the commute to work. Commutes account for only about 15 to 20% of all trips. However, even comparing mode shares for the commute to work, annual per capita CO_2 emissions from ground passenger transport shows higher CO_2 emissions and less walking, cycling, and public transport use in the USA (3,800 kg, 8% of work commutes by foot, bicycle, and public transport) than in Australia (2,300 kg, 17%) and Canada (2,900 kg, 18%) [32].

Americans not only make a higher share of trips by car, but they also drive longer distances. Compared to Germans, Americans drive almost twice as many miles per year: 13,500 vs. 6,800 passenger miles of car travel (21,700 vs. 11,000 passenger km). Longer average trip distances in the USA (9.8 miles/15.7km) than in Germany (7.0 miles/11.2km) do not fully explain different driving rates. For example, in both countries a similar share of all trips (32% in Germany and 27% in the USA) is shorter than 1 mile (1.6km). However, Americans drive for 65% of these short trips compared to only 28% of Germans [30, 31].

Average population densities are higher in German cities than in the U.S. However, even controlling for population density Germans are more likely to walk, cycle, and ride public transport. Americans living in dense, mixed-use areas, and close to public transport are even more likely to drive than Germans living in lower density areas, with more limited mix of land-uses, and farther from public transport [34].

Public policies at federal, state, and local levels of government help explain differences in car use. Table 2 provides a short overview of policies towards driving, public transport, walking, and cycling in Germany and the USA. The text briefly summarizes German federal government policies that make car use less attractive and help promote walking, cycling, and public transport. The table and the text below summarize previous research by the author [7, 35, 36].

4.1 Gasoline Taxes and Funding for Roads

In 2010, the cost of one liter of gasoline (95 Research Octane Number (RON) unleaded) was $1.75 in Germany compared to $0.74 in the USA [37]. Most of the difference was due to 8-times higher gas taxes in Germany compared to the USA. In 2010, taxes accounted for 62% of the retail price of gasoline in Germany compared to only 18% in the USA [37].

The difference in gasoline retail price between Germany and the USA has been increasing. In 1986 gasoline cost about 80% more in Germany than the USA. In 2010, the price of gas was 2.4 times higher in Germany. This divergence is partly explained by Germany’s environmental tax reform that increased gasoline taxes annually by €0.03 per liter ($0.14 per gallon) between 1998 and 2003—totaling €0.15 per liter ($0.71 per gallon) over 5 years [38]. The tax was designed to curb energy use from transport and to encourage more fuel efficient cars and less driving. The policy of annual increases expired in 2003, but the five-year implementation of the environmental tax helped boost gas taxes and prices permanently. By contrast the federal gasoline taxes in the USA have not been raised since 1993.

Revenue from highway user taxes and fees in Germany was 2.2 times higher than government road spending in 2010. By contrast, highway users receive net subsidies in the USA. In 2009, highway user revenue collected by federal, state, and local governments in the US covered only 58 percent of highways spending by all levels of government [39]. Moreover, since 2008 the federal Highway Trust Fund, which receives the revenues from the federal gas tax, has been supplemented with general funds several times.

Higher gasoline taxes do not lead to higher household expenditures for transport in Germany. In fact, US households spend about $2,500 more per year on transport—with transport accounting for 17% of household expenditures in the USA compared to less than 15% in Germany [32, 40].

On the local level, most German cities have increased the cost and/or reduced car parking in city centers and many neighborhood. In the USA the vast majority of automobile trips (95%) are still subsidized with free car parking [41]. Driving is also slower in German cities. In contrast to the USA, limited access highways in Germany rarely penetrate cities and city centers. In the USA, the federal government subsidized the construction of limited access highways in most US cities with as high as a 90% federal share [42]. The lack of high-speed highways in cities, combined with widespread traffic calming of residential neighborhoods restricts car travel and makes it slower in German cities. Most German cities, including large cities like Berlin and Munich, have traffic calmed over 70% of their road network to speeds of 30km/h (19 mph), and even walking speed (7km/h or 4mph) for some residential streets [43].

Tolling passenger cars for stretches of highways, new added lanes, bridges, and tunnels has been more common in the USA than in Germany. Trucks are tolled on the German Autobahn, but there is no charge for passenger cars [44]. Moreover, the German Autobahn network still has many stretches without speed limits, compared to speed limits between 65 and 75mph on the U.S. interstate system in most states [44].

4.2 Policies that Promote Public Transport, Cycling, and Walking as Viable Alternatives to Driving for Daily Travel

Higher costs for driving and more restrictions on car use in German cities help explain less car travel demand and lower CO_2 emissions from transport in Germany compared to the USA. Moreover, all levels of government in Germany have implemented policies that help make walking, cycling, and public transport attractive alternatives to driving (see table 2 for details). For example, public transport is more attractive in Germany because of higher levels of public transport service and more ubiquitous access to public transport. In 2009, public transport service, measured as vehicle kilometers of service per person, was three times greater in Germany than in the USA (60 vs. 20 vehicle kilometers per person per year). Moreover, 88% of Germans lived within 1 km of a public transport stop, compared with only 43% of Americans [45].

Public transport use per capita is also higher. Germans make 6.5 times as many public transport trips per year as Americans (135 vs. 21 trips per person per year) [46]. As shown by a recent study [46], more attractive public transport in Germany can additionally be explained by regional integration of public transport services, multi-modal coordination with other modes of transport, region-wide fare integration across operators, steeply discounted monthly and annual tickets, unified user information systems, real-time information at transit stations and on-board vehicles, as well as traffic priority for buses and light rail [46].

In the USA, most public transport trips are concentrated in large cities with subway systems and regional rail, such as New York City, Boston, Philadelphia, Washington (DC), Chicago, and San Francisco [47]. Moreover, public transport service in suburban areas and many cities typically focuses on commute hours with service going towards downtown in the morning and away from downtown in the late afternoon. Even though many public systems have made progress during the last decades, regional integration of timetables and ticketing, steeply discounted monthly tickets, and real-time passenger information are still rare or non-existent in most of the USA [48].

The German federal government plays a minor role in promoting walking and cycling—mainly limited to federal traffic laws protecting cyclists and pedestrians and making their safety an integral part of the German driver's license test [49]. Most innovations, such as car-free pedestrian zones, area-wide traffic calming, integrated city-wide bicycling networks, bicycling training courses for school children, and pedestrian-activated traffic signals were pioneered and implemented at the local and state level. The German federal government supported these efforts with technical guidance and flexible funding mechanisms, which allowed municipalities to use federal funds for non-motorized modes [49].

Since the 1990s the U.S. federal government has made an increasing amount of federal funds eligible for walking and cycling projects on the local and metropolitan level [50, 51]. Some US cities have used this opportunity to promote walking and cycling. However, most US cities still lack integrated networks of bike paths and lanes [51]. Moreover, many suburban settlements in the USA do not have sidewalks or crosswalks for pedestrians. Driver's training in the USA does not emphasize the rights of pedestrians and cyclists. Even though some cities have made progress, the USA is still less bike and pedestrian friendly than Germany. For example, in 2010, cyclist and pedestrian fatality rates per km cycled or walked were 4 to 5 times greater in the USA than in Germany [49].

Federal involvement in land-use planning in Germany is limited to defining the legal framework for planning, ensuring consistency of planning techniques, and—in collaboration with the states—setting broad strategic goals for spatial development, such as sustainability [52]. Municipal governments develop the actual land-use plans and decide where different land uses are permitted. Local plans in Germany are restricted by regional and state plans—which are developed with the involvement of lower levels of government. Moreover, land-use plans must be coordinated with other sectors (e.g. transport) and neighboring jurisdictions [53].

By contrast land-use planning in the USA is typically in the domain of municipalities, rarely coordinated across jurisdictions, and typically not integrated with transport planning. Additionally, mixed land use and dense development typically require changes to existing zoning codes in the USA [52]. German land-use planning is more flexible, because ‘residential zones’ allow for doctor’s offices, small shops, restaurants, and multi-family housing. Moreover, in the USA, areas zoned as ‘single family residential’ ban any mixed land uses or multi-family homes. German zoning typically applies to small areas (one block or a couple of blocks), while zones in the USA are typically much larger. Fine-grained zoning in Germany allows for a better mix of land-uses that results in shorter trip distances [54].

Policy	Country	Description
Policies that make car us less attractive in Germany than the USA		
Sales tax for new cars	***USA:***	State sales taxes for new car purchases range from 0% to 8.25%, with an average of 4.9%
	Germany:	19% in all states
Drivers license & cost	***USA:***	Easy and cheap driver training and licensing, costing about $100 in most states
	Germany:	Strict and expensive driver training and licensing, costing over $2,000 per license
Price of gasoline	***USA:***	In 2010: $0.74 per liter (18% of price is tax)
	Germany:	In 2010: $1.75 per liter (62% of price is tax)
Road revenues & expenditures	***USA:***	Road user taxes and fees account for 58% of roadway expenditures by all levels of government
	Germany:	Roadway user taxes and fees are 2.2 times higher than roadway expenditures by all levels of government
Traffic calming & speed limits	***USA:***	Few cities have any traffic-calmed neighborhoods; Speed limits on most city streets range from 35 to 45 mph (56 to 72 km/h)
	Germany:	Most residential streets are traffic-calmed at 30km/h or less, with speeds reduced to 7 km/h on some residential streets; General speed limit of 50km/hr (33mph) in cities
Road & parking supply	***USA:***	High-speed motorways and arterials criss-cross cities and suburbs; Municipal zoning codes require high levels of minimum parking
	Germany:	High-speed motorways rarely penetrate into city centers; Most cities have reduced car parking in downtowns and increased parking fees since the 1960s
Policies that make public transport more attractive in Germany than the USA		
Quantity of service	***USA:***	20 vehicle kilometers of service per capita per year: regional rail & metro: 6km; bus & light rail: 14km
	Germany:	59 vehicle kilometers of service per capita per year: regional rail & metro: 28km; bus & light rail: 31km
Quality of service	***USA:***	Many systems have modernized their vehicles and stations; Little coordination of services and ticketing across modes and operators
	Germany:	All systems have modernized their vehicles and stations; Full coordination of schedules and routes across modes and operators
User information	***USA:***	Fragmented, incomplete, and often undependable information; Real-time information rare even on trains, almost never on buses (except BRT)
	Germany:	Online information about regional, state-wide, & national routes, timetables, and fares; Real-time information at most rail & some bus stops, and on-board most trains & buses
Discounts	***USA:***	Public transport commuter tax benefits; Discounts for seniors; Slightly discounted monthly tickets for regular commuters; Discounts for off-peak travel provided by some systems
	Germany:	Tax benefit based on daily commute distance; Discounts for children, university students, and seniors; Deeply discounted monthly tickets available to all groups
Region-wide integration	***USA:***	Fares and ticketing rarely integrated across operators and jurisdictions; Regional transport planning authorities in most cities, but with less integration of services than in Germany
	Germany:	Regional public transport authorities integrate fares, ticketing, operations, & financing across operators and jurisdictions; State-wide coordination of schedules, fares, & tickets
Policies that make walking and cycling more attractive in Germany than in the USA		
Federal subsidies	***USA:***	Federal transport funds eligible for walking and cycling projects; special federal funds for non-motorized transport; State DOTs are required to have pedestrian and cycling staff
	Germany:	Earmarked federal funds for improvement of urban pedestrian and cycling facilities; Federal funding for bike paths along highways
Car-free zones	***USA:***	No area wide pedestrian zones; pedestrianized streets exist in some cities, such as Madison (WI), Minneapolis (MN), or Denver (CO)
	Germany:	Most cities have pedestrianized large areas of their downtown that are off-limits for automobiles
Traffic calming	***USA:***	Cities experiment with traffic calming; applications are not as systematic and comprehensive as in German cities
	Germany:	Almost all cities have traffic calmed most residential streets to 19 mph (30 km/h); Certain areas limit cars to walking speed (4 mph / 7 km/h)
Pedestrian facilities	***USA:***	Lack of pedestrian facilities in many developments and along many urban roads; New complete streets policies in many cities consider the needs of all modes
	Germany:	Universal provision of sidewalks in urban areas; Priority for pedestrians in car-free zones in downtowns in almost all cities
Bikeway networks	***USA:***	Only few cities have an integrated network of bicycling facilities
	Germany:	Majority of cities with comprehensive, region-wide integrated networks of separate facilities for cyclists
Traffic education	***USA:***	Voluntary bicycling courses; Rarely any education of drivers, pedestrians and cyclists about rights of pedestrians and cyclists; Safe routes to school in all states with dedicated staff
	Germany:	Safe and effective cycling training is part of school curriculum; Rights of non-motorized modes are part of driver's training and testing
Land-use planning and policies that facilitate more dense and mixed land-uses that facilitate walking, cycling, and public transport use		
Coordination with public	***USA:***	Little coordination of transport with land-use planning, except for some Transit Oriented Developments (TOD)
	Germany:	Strict land-use controls limit low density sprawl and encourage compact development around public transport stops
Planning process	***USA:***	No federal land-use planning; Limited state land-use planning; Uncoordinated, and often conflicting land-use planning by local jurisdictions
	Germany:	Coordination of land-use plans among levels of government and across jurisdictions; Integration of land-use, transport, and environmental planning at all levels of government

TABLE 2. Comparison of Key Transport Policies in Germany and the USA that Restrict Car Use and Promote Walking, Cycling, and Public Transport for Daily Travel. ***Based on:[44, 46, 49]***

5. DISCUSSION AND CONCLUSIONS

CO_2 emissions from transport are much higher in the USA than in Germany, even when controlling for population, economic activity, and travel distance. Between 1990 and 2010, Germany has reduced CO_2 emissions from ground passenger transport. Passenger transport CO_2 emissions per capita and per km of travel also declined in the USA, but only between 2005 and 2010 during the economic crisis and in the face of volatile fuel prices. In both countries regulations attempt to improve the fuel efficiency of the vehicle fleet using CO_2 tailpipe emission standards and incentives for less polluting vehicles and fuels.

The U.S. experience shows that fuel efficiency (and by extension CO_2 emission) standards can help boost fuel efficiency of new vehicles, but it also highlights the difficulty of adapting the standards to changing technology, politics, and societal preferences. Between the mid/late 1980s and the mid/late 2000s, it was politically difficult to significantly increase fuel efficiency standards in the USA. During that time, policymakers also failed to adapt CAFE standards to the increasing use of light trucks as private vehicles. As a result most progress in vehicle technology and fuel efficiency during that time was off-set by heavier and larger vehicles.

New EU standards may run the same risks as CAFE standards in the USA. Germany's government—likely reflecting the position of the country's automobile industry—has already attempted to delay implementation of the stricter 95g CO_2/km standard from 2020 to 2024. Moreover, EU standards offer fewer incentives than US standards to raise the fuel efficiency of increasingly popular larger vehicles. In the EU more fuel efficient, lighter vehicles, are subject to stricter standards. In the US a lighter vehicle (with the same floor area as a heavier vehicle) can help improve a manufacturers overall CO_2 emissions rating.

Government incentives for the purchase of more fuel efficient cars with lower CO_2 emissions, such as special tax credits or no/lower annual registration fees, can help increase demand for those vehicles, but the overall volume of the programs is often too small or incentives are too little. For example, during the economic crisis in 2009 'cash for clunkers' programs in both countries were successful in replacing older less fuel efficient vehicles with newer more efficient cars. However, in spite of the total cost of $7.5billion (Germany) and $3 billion (USA), the volume of cars bought under the two programs was too small to have a significant impact on the overall fuel economy of the vehicle fleet. Similarly, the CO_2 component of Germany's annual vehicle registration fee is too small to have a significant impact on the overall vehicle fleet.

The analysis also shows that Germany achieved higher fuel economy of its vehicle fleet and greater reductions in CO_2 emissions from transport than the USA without fuel economy or CO_2 emission standards. This indicates that policies focusing on technological improvements can only be part of a policy package geared at reducing CO_2 emissions from transport. Technological improvements alone are prone to the potential rebound effect of heavier vehicles, larger engines, and greater car travel demand. Germany's experience shows that public policies can also help reduce car travel demand while making walking, cycling, and public transport more attractive modes of transport.

Recent trends in travel demand and travel preferences among young adults may provide a window of opportunity for policies that promote walking, cycling, and public transport. Studies suggest that western European countries experience a 'peak car' phenomenon where overall car travel demand either increases very slowly, stagnates, or declines [55-57]. Young adults between 20 and 30 years seem to lead this trend by driving less, owning fewer cars, and using other modes of transport more often than previous generations [58]. Some studies also report stagnating or declining overall travel demand in the USA [55]. However, it remains to be seen if these trends continue once the US economy and employment rebounds from the 2009 crisis and if gas prices decline again. In any case, more attractive public transport service and better infrastructure for walking and cycling may increase future use of those modes in the USA, especially for those individuals who reduced their driving and shifted to alternatives means of travel in response to the economic crisis and high gasoline prices.

Germany's policies that promote walking, cycling, and public transport and restrict car use can provide lessons for the USA. However, policies from Germany cannot be imported wholesale, but have to be adapted to the US context. The most important lesson from Germany is the combination of 'push policies' that restrict car use and make it more expensive with 'pull policies' that make alternatives to the car more attractive. Some U.S. cities, such as Portland, Oregon or New York City, have adopted policies that promote public transport, walking, and cycling, as viable alternatives to the car. However, the biggest difference between Germany and the USA is that U.S. cities rarely implement measures that restrict car use by making it more costly, slower, and less convenient. Incentives for public transport, walking, and cycling can make car restraint measures more feasible and successful. Once walking, cycling, and public transport are viable options for some trips, it becomes politically easier to implement car restraint measures.

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