Sustainable Transport that Works: Lessons from Germany

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1. Introduction. In recent years, countries in Europe and North America have increasingly recognized the need to improve the social, environmental, and economic impacts of transport. Yet most countries are far from achieving the goal of transport sustainability (Banister, 2005, Banister *et al.*, 2007). The USA is perhaps the best known example of unsustainable transport, but most of the world's countries have been heading in the wrong direction as well. That is mainly due to rapidly increasing reliance on the private car for daily travel (Newman and Kenworthy, 1999, Vuchic, 1999, Low and Gleeson, 2002, Tolley, 2003).

The car is popular among consumers because it generally provides high levels of mobility and convenience. As many studies have shown, car ownership and use rise rapidly with increased income. The increasing affordability of cars is the most important explanation for the worldwide growth in motorisation in recent decades (Ingram and Liu, 1999, Schafer and Victor, 2000, Downs, 2004). Moreover, as car use increases to ever higher levels, the car tends to drive out competing modes, thus limiting travel options. That is partly due to the car's genuine benefits, but also results from the negative impacts of car use on other modes. For example, cars are the main source of traffic dangers for pedestrians and cyclists, thus discouraging walking and cycling (Tolley, 2003, FHWA, 2004, IRTAD, 2008, FHWA, 2009). By congesting roadways, cars slow down buses and discourage public transport use(Downs, 2004, Vuchic, 2005). Cars also encourage lower density, sprawled development that is difficult to serve with public transport and generates trip distances too long to walk or cycle (Schaefer and Sclar, 1980, TRB, 1998, 2001, Pacione, 2007). Thus, rising car use reduces the attractiveness of alternative modes and induces a further modal shift toward the car. For all these reasons, the relatively sustainable modes of public transport, walking and cycling have been losing market share in most of the world (Newman *et al.*, 1999, Banister, 2005).

Although the car provides extraordinary mobility and convenience for most travel needs, it also causes serious social, economic, and environmental problems. Technological improvements in recent decades have made cars less polluting, more energy efficient, and safer, but they remain a major source of air and water pollution, noise, energy use, and traffic injuries. Moreover, problems such as congestion, suburban sprawl, and inequity are less amenable to technological solutions. Improving the public transport, walking, and cycling alternatives to the car must be a cornerstone of any program to increase the overall sustainability of our transport systems. It would increase the range of choice for all travellers, even those whose general preference is for the car.

This paper examines the case of Germany, and how it has managed to balance high levels of car ownership with safe and convenient public transport,

cycling, and walking alternatives. It shows that the car can peacefully co-exist with other modes of transport, provided the right policies are adopted to restrict car use in those situations where it is most problematic. The overall result is a transport system that is far more sustainable in Germany than in the USA even though Germans have one of the world's highest car ownership rates. Moreover, Germany was able to implement the necessary transport, land use, and taxation policies in spite of its important car manufacturing industry, a powerful car lobby, and the immense popularity of cars among German consumers (Wolf, 1986, Schmucki, 2001). The German experience suggests that the most feasible way to improve transport sustainability is to tame the automobile, not to eliminate it. At the same time, public transport, cycling, and walking must be improved to provide feasible alternatives to car use, and thus to make car restrictive policies politically feasible.

After examining the overall approach in Germany, we focus on the city of Freiburg in southwestern Germany, which is often called the environmental capital of Germany and widely considered its most sustainable city. The innovative transport and land use policies introduced there since the 1970s have spread to many other German cities. Freiburg offers useful lessons on how to increase transport sustainability, refuting the notion that sustainability cannot be economically viable. As shown in this article, Freiburg's transport reforms have increased the overall efficiency of its transport system and triggered an economic boom that has made Freiburg one of Germany's most sought-after locations both for business and residence. Freiburg demonstrates that sustainable transport can work very well indeed.

2. Comparison of German and US travel trends and sustainability. As shown in Table 1, car ownership increased faster in Germany than in the USA from 1950 to 2006. Indeed, the motorisation rate rose 42-fold in Germany, albeit from a very low base of only 13 cars per 1,000 inhabitants in 1950 (KBA, 2006). In 2006, the USA still had roughly a third more cars per capita than Germany (776 vs. 546), but the German rate is one of the highest in the world and second highest in Europe after Luxembourg. In spite of its high rate of car ownership, Germany's car use per capita in 2005 was less than half that in the USA (7,040 vs. 14,800 veh. km) (FHWA, 1990-2008, BMVBS, 1991-2008, FHWA, 2006). Moreover, the rate of increase in car use in Germany has been less than half as fast as in the USA in recent years. From 1995 to 2006, for example, passenger km of car use per inhabitant increased by 6% in Germany compared to 14% in the USA (FHWA, 1990-2008, BMVBS, 1991-2008, FHWA, 2006).

Table 1: Auto Ownership Trends, 1950 – 2006

	Freiburg	Germany	Europe	U.S.	World
1950	28	13	18	268	25
1960	113	82	41	306	34
1970	248	208	135	389	54
1980	361	375	241	573	74
1990	422	445	288	613	81
2000	420	532	427	746	94
2006	419	546	466	776	97

Sources: *FHWA (1990-2008), BMVBS (1991-2008), Pucher and Clorer (1992), OECD (2003-2007), EUROSTAT (2005-2007), City of Freiburg (2009b)*
Note: Until 1989 West Germany only; West and East Germany after reunification in 1990.

One reason for the much higher level of car use in the USA is the higher car share of trips in the USA compared to Germany. National travel surveys with very similar methodologies and timing measured a car share of 87% for the USA in 2001 and 61% for Germany in 2002 (BMVBS, 2004, ORNL, 2005). The car dominates even for short trips in the USA: 67% of all trips of a mile or less, compared to 27% in Germany (Buehler, 2008). Conversely, public transport accounts for five times as high a share of trips in Germany as in the USA: 8.5% vs. 1.6%. Similarly, walking and cycling account for three times as high a share of trips in Germany as in the USA: 32% vs. 10%.

The greater car-dependence in the USA suggests that its transport system is less sustainable than Germany's, and the available statistics support this impression (see Table 2). In 2006 per capita energy use and CO_2 emissions from personal transport were only about a third as high in Germany as in the USA. Moreover, as with car use, the trend is more favourable in Germany. Per-capita energy use for personal travel fell in Germany by 8.5% between 1999 and 2006, and CO_2 emissions fell by 7%. Over the same period, transport energy use per capita rose by 4% in the USA and CO_2 emissions rose by 2% (BMVBS, 1991-2008, UBA, 2005c, FHWA, 2006, DOE, 2007).

Table 2: Passenger Travel and Sustainability in Germany and the USA

ENVIRONMENT			
Dimension	**Indicator**	**USA**	**GERMANY**
GHG Emission (2005)	Car CO_2 emissions (car and light truck use per capita in kg)	3,900	1,300
Car Fuel Efficiency (2005)	Miles per gallon (existing vehicle fleet of cars and light trucks)	20	30
Passenger Transportation Energy Use (2004/2005)	Mega joules per person year	58,000	18,000
	Mega joules per passenger kilometre		
	Cars and light trucks avg.	4.1	2.0
	Transit bus	4.5	1.1
	Light rail	2.9	1.3
	Heavy rail	2.7	1.5

ECONOMIC & SOCIAL			
Dimension	**Indicator**	**USA**	**GERMANY**
Household Transport Expenditures (2003)	% of household budget for transport (2003)	19%	14%
Traffic Safety (2002-2005)	Traffic fatalities per 100,000 population	14.7	6.5
	Traffic fatalities per kilometre of travel		
	Cyclist fatalities per 100 million km	11.3	2.5
	Pedestrian fatalities per 100 million km	5.0	2.5
	Car fatalities per billion km	9.0	7.8
Transit Subsidies (2006)	Government subsidy as share of public transportation operating budgets in %	70%	33%

Sources: FHWA (1990-2008), BMVBS (BMVBS, 1991-2008), DESTATIS (DESTATIS, 2003), U.S. Department of Labour (2003), Pucher (2004), UBA (2005c), APTA (2006), (2006), FHWA (2006), IRTAD (2006), ORNL (2008), Pucher and Buehler (2008), VDV (VDV, 2008)

In addition to less car dependence, Germans drive far more fuel efficient cars. Cars and light trucks in Germany averaged 30 mpg in 2005, compared to only 20 mpg for cars and light trucks in the USA. Public transport is also more fuel efficient in Germany than in the USA, averaging only half as much energy per vehicle km and only a third as much energy per passenger km.

Social and economic indicators show greater sustainability in Germany. Traffic fatalities per capita in 2006 were 2.3 times higher in the USA than in Germany, indicating an important gap in overall travel safety. The difference is especially pronounced for walking and cycling, which are less than a third as dangerous in Germany as in the USA when measured by fatalities per trip and per km travelled. Even car travel is safer in Germany, with slightly fewer fatalities per km driven than in the USA (7.8 vs. 9.0 deaths per billion km).

Travel in the USA costs more money, both for individual households and for the public sector. On average, Americans spend 19% of their household budget for transport compared to 14% in Germany. That translates into $2,712 more per household per year in the USA than in Germany (DESTATIS, 2003, U.S. Department of Labor, 2003). Clearly, car-dependence comes with a high price tag.

Another aspect of economic sustainability is the degree to which government subsidies are required for transport. Germany has three times as much public transport service per capita as the USA (56 vs. 19 veh. km of service per year) and four times as much public transport use per capita (1,145 vs. 269 passenger km per year) (VDV, 2005, APTA, 2006, VDV, 2006). Nevertheless, government subsidies to public transport are much smaller in Germany than in the USA. Passenger fares cover an average of 72% of operating costs in Germany compared to only 35% in the USA, and the average operating subsidy per passenger trip is twice as high in the USA ($.40 vs. $.20 in 2004) (VDV, 2005, APTA, 2006).

In short, along every dimension transport is more sustainable in Germany than in the USA. The following section examines briefly the overall transport, land use, and taxation policies in Germany that have enabled this achievement.

3. Overview of German transport, land use and taxation policies. There are five categories of government policies that have been particularly important for transport sustainability in Germany. First, taxes and restrictions on car use help limit car use and mitigate its harmful impacts. Second, the provision of high-quality, attractively priced, well-coordinated public transport services offers a viable alternative to the car for many trips, especially in large cities. Third, infrastructure for non-motorized travel has been vastly improved to increase the safety and convenience of walking and cycling. Fourth, urban development policies and land use planning have encouraged compact, mixed-use development, discouraged low-density suburban sprawl and thus kept many trips short enough to make by walking or cycling. Fifth, all of these policies have been fully coordinated to ensure their mutually reinforcing impact.

3.1. Pricing and restrictions on car use. The overall cost of owning and operating a similar car is about 50% higher in Germany than in the USA (AAA, 2007, ADAC, 2007). Most of that difference is due to much higher taxes and fees on car ownership and use in Germany. In particular motor fuel taxes in 2006 were nine times higher in Germany than in the USA. Moreover, the gap between German and American prices has increased over time (EIA, 2008, IEA, 2008). In 1990, petrol cost about 70% more in Germany than in the USA. In 2006, petrol cost 107% more. That is partly due to an explicit policy of regular, annual increases in the petrol tax in Germany during the five years from 1999 through 2003, when the Green Party was part of the coalition government (UBA, 2005a).

As taxes on motor vehicle ownership and use have increased in Germany, the resulting revenues have covered an increasing percentage of government expenditures on roadway construction and maintenance—from 92% in 1975 to 259% in 2006 (BMVBS, 1991-2008). Over the same period, the percentage of roadway costs covered by motorist charges in the USA actually fell from 0.70 to 0.63 (FHWA, 1990-2008).

Compared to the USA, German cities place far more restrictions on car use through limited road supply, lower speeds, and less parking. American metropolitan areas are encircled and crisscrossed by numerous high-speed beltways and expressways that penetrate into the heart of almost every city (TRB, 1998). Even though Germany has the fastest and third largest motorway network in the world, German motorways rarely penetrate into the city centre (Pucher, 1995, IRF, 2007). The greater supply of roadways in metropolitan areas might explain why average car speeds in the USA were 25% higher than in Germany in 2001/2002 (Buehler, 2008).

The layout of roads within German cities also restricts car travel. Extensive car free zones in most German cities—combined with deliberate dead-ends, turn restrictions and one-way street networks—have made it difficult, if not impossible, for cars to get from one side of the city to the other by passing through the city centre (Pucher, 1988, Hajdu, 1989, Hass-Klau, 1993b, Topp, 1993).

Moreover, roughly 70-80% of the road network in German cities and small towns has speed limits of 30km/hr or less (Beatley, 2000, Newman *et al.*, 2009). Almost all residential neighbourhoods employ speed-inhibiting measures such as "Tempo 30" signs,

road narrowing, raised intersections and crosswalks, traffic circles, extra curves and zigzag routes, speed humps, and artificial dead-ends created by mid-block street closures (Topp, 1994, Bundesregierung, 1998, BMVBS, 2002). Many residential streets in Germany—both in the central city and in new suburban developments—impose even lower speed limits, requiring cars to travel at 'walking speed,' set at 7km/hr for legal purposes (Beatley, 2000). Traffic calming is usually area-wide and not for isolated streets. That ensures that thru-traffic gets displaced to arterial roads designed to handle it and not simply shifted from one residential street to another.

The ultimate restrictive measure is to ban cars altogether. Virtually all German cities have created car-free zones in their centres, mainly intended for pedestrian use but generally permitting cycling during off-peak hours (Hajdu, 1989, Hass-Klau, 1993b, Beatley, 2000, GTZ, 2004). Another measure discouraging car use in German cities is the high price and restricted supply of parking (BAST, 2004, Boltze and Schaefer, 2005).

3.2. Public transport improvements

Germany offers far more extensive, higher-quality, and better integrated public transport services than in the USA. Thanks to continuous improvements to German public transport in recent decades, public transport use has continued to grow in spite of rapid growth in per-capita income and car ownership. From 1970 to 2005, for example, public transport trips per capita rose from 116 to 133 in Germany, while they fell in the USA from 23 to 21, less than a sixth the level in Germany (TRB, 2001, VDV, 2005, APTA, 2006, VDV, 2006).

German public transport is far more economically sustainable than American public transport (BMVBS, 1991-2008, VDV, 2005, APTA, 2006). That is due to higher passenger fare revenues in Germany as well as lower costs. The main reason for higher revenues is that German buses, trams, metros, and trains have more than twice as many passengers per vehicle as their American counterparts. Costs are lower for many reasons. German public transport vehicles are generally quite new, thus increasingly reliability and avoiding the high maintenance costs for old vehicles. German buses and trams are often articulated, carrying more passengers and requiring fewer drivers per passenger. That saves on labour costs, which are further reduced through the use of part-time labour to handle the extra service during peak hours. Labour productivity, as well as service quality, are yet further enhanced by signal priority at intersections and by wider spacing of bus and tram stops to avoid frequent stops. The resulting increased bus and tram speeds raise labour productivity by increasing the average vehicle km of service per driver hour (TRB, 2001, VDV, 2008). Thanks to higher revenues and lower costs, German public transport requires much smaller operating subsidies: only 28% of total operating costs, compared to 67% in the USA (VDV, 2005, APTA, 2006).

Another reason for the success of German public transport is the multi-modal coordination of public transport services, fares, and schedules within metropolitan areas. Starting with Hamburg in the 1960s, one German city after another created regional public transport organisations (Verkehrsverbuende), which fully integrated all aspects of public transport

operations and financing (Pucher and Kurth, 1996). By 1990, virtually all metropolitan areas in Germany had such public transport organizations, which have expanded and improved services, vastly improved fare structures, and attracted large increases in passengers (TRB, 2001). As a result, transfers between different types of public transport, different routes, and different operators are virtually seamless for passengers, both in terms of timing as well as distance walked. Additionally, German systems offer deep discounts on weekly, monthly, annual, and semester tickets that make it economical and convenient to use public transport on a daily basis and competitive with cars for the commute to work (VDV, 2005, 2006).

German public transport systems also do a better job of integrating their services with walking and cycling facilities. Wide sidewalks, safe pedestrian crossings, and car-free zones facilitate pedestrian access to bus and rail stops. Virtually all German public transport systems provide extensive bike parking facilities (Pucher and Buehler, 2008).

Public transport is more successful in Germany not because of more money but because of far more effective use of subsidies, much better fare and service policies, and the much higher cost of car use.

3.3. Walking and cycling in Germany

Especially since the 1970s, virtually all German cities have greatly improved transport infrastructure used by pedestrians and bicyclists (BMVBS, 2002, 2008). For pedestrians, that has included car-free zones that cover much of the city centre and wide, well-lit sidewalks on both sides of every street. Other pedestrian friendly design features include pedestrian refuge islands for crossing wide streets; clearly marked zebra crosswalks, often raised and with special lighting for visibility; and pedestrian-activated crossing signals (Pucher and Dijkstra, 2003). All residential and commercial developments have sidewalks for pedestrians, and many feature separate bike paths and extensive parking for cyclists.

The bicycling and walking networks in virtually all German cities include numerous off-street short cut connections for cyclists and pedestrians to enable them to take the most direct possible route from origin to destination. The result of such a wide range of facilities is a complete, integrated system of bicycling and walking routes that permit cyclists and pedestrians to cover almost any trip either on completely separate paths and lanes or on lightly travelled, traffic-calmed residential streets (Pucher and Buehler, 2008).

Most bicycling and pedestrian infrastructure is financed with local funds, but often with substantial state and federal subsidies (Bundesregierung, 1998, BMVBS, 2002). Indeed, a special federal urban transport fund allows 70-85% federal matching funds for state and local expenditures on facilities for cyclists and pedestrians, including paths, lanes, bridges, bike parking, traffic signals, and signs.

Germany has greatly increased pedestrian and cyclist safety since 1970, while it has only slightly increased in the USA. For example, the number of cyclist fatalities fell by almost 80% in Germany over the past 35 years, compared to a decline of only 30% in the USA (Pucher and Dijkstra, 2003, Pucher and Buehler, 2008). That is especially impressive given the cycling boom in Germany between the mid-1970s and the mid

1990s, when cycling levels doubled or tripled in most cities. Averaged over the years 2002 to 2005, pedestrian and cyclist fatality and injury rates were only a third as high in Germany as in the USA (IRTAD, 2008).

Greater pedestrian and cycling safety in German is largely due to a range of government policies that promote it. Extensive networks of bike paths and lanes on busy arterial streets, priority traffic signals at intersections, and comprehensive traffic calming of residential neighbourhoods enhance the safety of walking and cycling (BMVBS, 2002). Rigorous training of both motorists and non-motorists in traffic safety is required. These explicitly pro-walk and pro-bike policies generally slow down car use and often shift roadway space from cars to non-motorized users (BMVBS, 2006).

3.4. Urban development and land use policies. Over the last 50 years, cities in both Germany and the USA have been decentralizing (Nivola, 1999, Burchell *et al.*, 2002, Divall and Bond, 2003, DIFU, 2004). Nevertheless, in 2003 the average population density of cities and suburbs was up to three times higher in Germany than in the USA. The greater mix of land uses and higher population densities in Germany lead to shorter average trip distances than in the USA, thus increasing the possibilities for walking and cycling. Moreover, higher population densities make public transport service more economical by generating higher passenger volumes. Differences in spatial development patterns between the two countries are not simply the result of the much older history of German cities. Far more important are differences in the organisation of the land-use planning process, property rights, zoning regulation, and local public finance (Nivola, 1999, Hirt, 2007, Schmidt and Buehler, 2007).

Perhaps most fundamentally, the right to develop property is highly circumscribed in Germany. With few exceptions, new development is limited by law to areas immediately adjacent to already built-up areas, thus avoiding leapfrog development and suburban sprawl (BMVBS, 1993).

In Germany, governments on the federal, state, regional, and local level interact in a bottom-up and top-down land-use planning process, which is based on cooperation, compromise, and mediation (BMVBS, 2000, Kunzmann, 2001). The specificity of land use plans increases from top to bottom. Additionally, at each level of government formal links exist between land use planning and other areas of planning such as transport and the environment (BMVBS, 2000, Fuerst and Scholles, 2003). Coordination of land-use planning in Germany is facilitated by less municipal competition for property taxes (Schmidt and Buehler, 2007).

The key to compact, mixed-use development in Germany lies in horizontal cooperation between jurisdictions at the same level of government, vertical cooperation between different levels of government, strict regulation of private development at the suburban fringe, zoning that encourages high density and mixed use, and tax sharing arrangements that minimize competition among cities and towns for tax base.

3.5. Coordinating policies. It is politically difficult and potentially inequitable to restrict car use and make it more expensive unless there are

feasible alternatives to car use that provide acceptable levels of mobility. Thus, car-restrictive policies must be accompanied by the provision of high quality public transport services as well as safe and convenient walking and cycling facilities.

Starting in the 1970s, German cities started imposing restrictions on car use and parking (Topp, 1994, Blatter, 1995, Topp, 1993). Since then, car-restrictive measures have been successively expanded. But at the same time, conditions for walking, bicycling, and public transport use have steadily improved, and these three alternatives to the car have been better coordinated with each other. As a result, the overall range of transport options improved for everyone. That is what made the entire package of policy reforms publicly acceptable and politically possible. Simply restricting car use, or making it more expensive, without providing good alternatives, would have been viewed as purely punitive measures and thus politically impossible.

The coordination of transport and land use policies is another area where Germany is ahead of the USA. In most German cities, transport and land use planning are usually conducted within the same local government department (BMVBS, 2000, Schmidt and Buehler, 2007). That is also true at the state and federal levels of government. Indeed, there is a combined Federal Ministry of Transport and Land Use in Germany to ensure coordination. There is no equivalent in the USA, neither at the state nor federal level of government. The explicit coordination of transport and land use is another key to the success of sustainable transport policies in Germany, since compact, mixed-use developments and crucial to the viability of walking, cycling, and public transport.

3.6. Transport policy reforms. Land use, urban development, and transport policies in Germany have not always been as sustainable as they are currently. On the contrary, government policies in the 1950s and 1960s generally aimed to adapt cities to the car, vastly expanding roadway supply and parking facilities while permitting car-dependent retail and residential developments on the urban fringe (Hajdu, 1989, Hass-Klau, 1993b, Koeberlein, 1997, Schmucki, 2001, TRB, 2001, BMVBS, 2008). As car use increased, roadway congestion got worse, and traffic fatalities rose sharply. With rising car traffic, noise and air pollution increased as well, and quality of life in many neighbourhoods suffered. These negative externalities of car use triggered a grassroots revolt that generated many of the progressive transport and land use policies in Germany today (BMVBS, 2008).

Stimulated further by the energy crisis of 1973, car-restrictive policies gradually became more widespread and better coordinated throughout the rest of the 1970s and continued to expand in successive decades. Most cities reduced car parking and increased its price, especially in the central city (BMVBS, 2008, Topp, 1993). More and more cities established car-free streets, which increased in number and connectivity over time to form extensive car-free zones (Hass-Klau, 1993a, Beatley, 2000). Over the past three decades, traffic calming of residential neighbourhoods has spread rapidly to virtually all Germany cities and towns.

In short, there was an important turn-around in German policies in the early

1970s. Ever since then, the trend has been toward more restrictions and higher taxes on car use, while walking, cycling, and public transport have been increasingly promoted through a wide variety of measures. That shift in transport policies was coordinated with a corresponding shift in land use policy, which increasingly fostered clustered urban development within walking distance of public transport while discouraging car-dependent development at the suburban fringe.

The German federal government provided the overall framework for sustainable transport policies by raising petrol taxes, decreasing spending on roads, and increasing investment in public transport. Nevertheless, German states and cities played the most important role in moving away from a car-dominated system toward one where there is genuine choice among modes. Most of the necessary land use and transport policies could only be implemented at the local level, and it is precisely there that one finds the most innovations in Germany.

Given that key role of cities, we focus now on Freiburg, which for decades has been at the vanguard of sustainable transport and land use policies. Its reputation for being the 'environmental capital' of Germany derives from the extraordinary range of measures Freiburg has implemented since 1970 to restrict car use, promote walking, cycling and public transport, and encourage development that promotes the quality of life while protecting the environment and saving energy.

4. Freiburg: Environmental capital of Germany

4.1. Background information. Freiburg is a city of about 220,000 inhabitants located in south-western Germany (Gutzmer, 2006, City of Freiburg, 2009b). It serves as the economic, cultural, and political centre of the Black Forest region, which had a population of 615,000 in 2005 (Gutzmer, 2006). Its economy is based on tourism, university teaching and research, government and church administration, and a broad range of services provided to the surrounding region. The development of Freiburg has been favoured by its ideal climate—sunnier and warmer and than other major city in Germany—and its key location at the gateway to the Black Forest and less than an hour's travel from Switzerland and France (Pucher and Clorer, 1992).

4.2. Trends in car ownership, travel behaviour, and sustainability. From 1950 to 1970, car ownership in Freiburg was higher than for West Germany as a whole, but since the dramatic policy reversal in the early 1970s, the rate in Freiburg has fallen further and further below the German average (see Table 1). Moreover, the motorization rate declined slightly between 1990 and 2006, from 422 to 419 cars per 1,000 inhabitants (City of Freiburg, 2009b). Whereas Freiburg had more than twice as many cars per capita as the West German average in 1950, it had 23% fewer cars per capita than the unified German average in 2006. That is a stunning turnaround and dramatic evidence of the impact of Freiburg's range of sustainable transport policies.

Available statistics confirm that Freiburg has become more sustainable over time and is more sustainable than Germany as a whole. In spite of rising per-capita income, vehicle km of car use per capita in Freiburg declined by 7% on all roads and by 13% on residential roads from

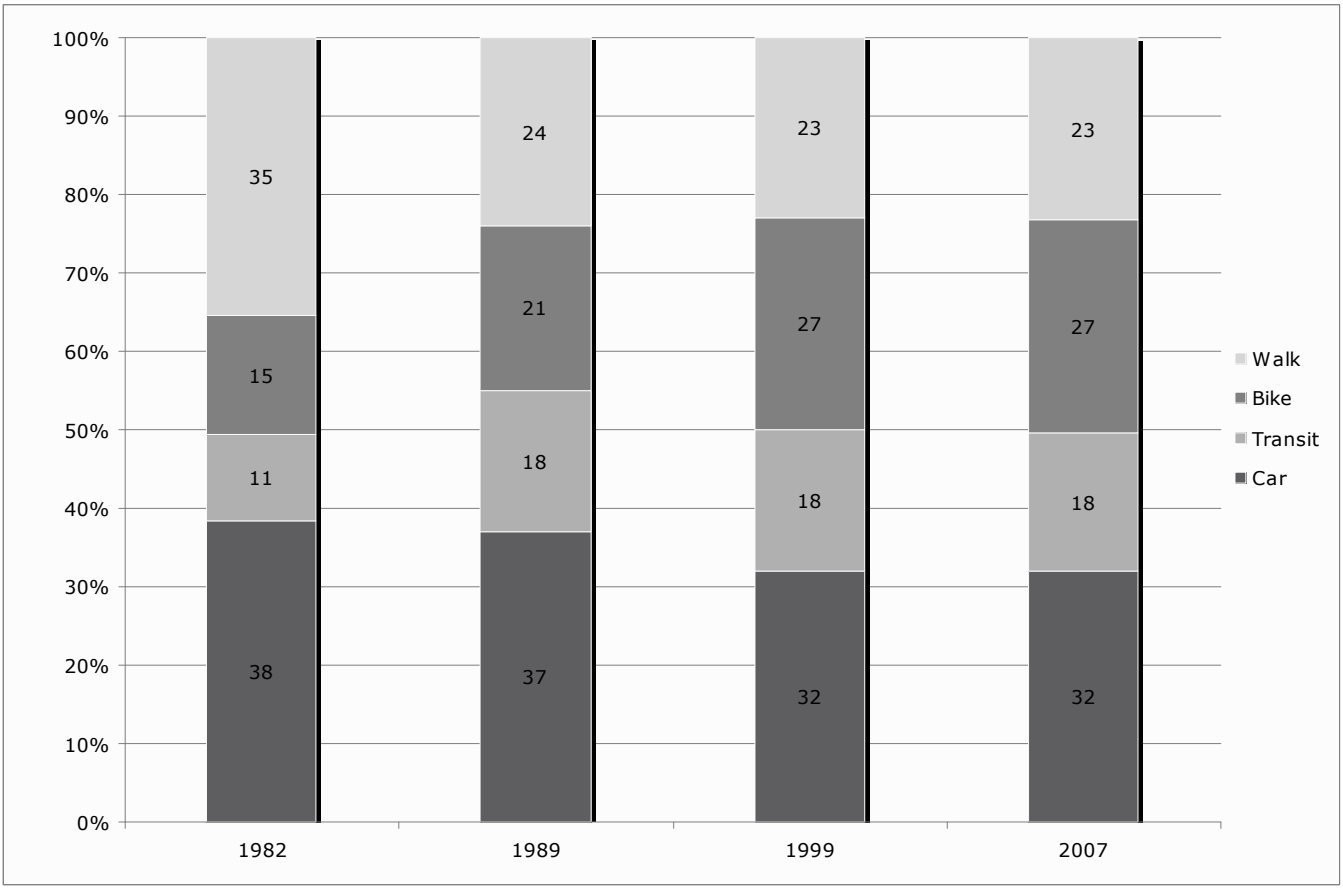
1990 to 2006 (City of Freiburg, 2007a, Oeko Institut, 2007, State of Baden Wuerttemberg, 2008). From 1992 to 2005, transport CO_2 emissions per capita in Freiburg fell by 13.4% to a level that is 89% of the German average and only 29% of the American average (City of Freiburg, 2005, UBA, 2005b, Oeko Institut, 2007, UBA, 2008). Travel is also safer in Freiburg than in Germany as a whole: 3.7 traffic fatalities per 100,000 inhabitants vs. 6.5 in Germany and 14.7 in the USA (NHTSA, 2004, INKAR, 2005, Polizeidirektion Freiburg, 2005). Finally, the financial viability of public transport is extraordinarily high in Freiburg, requiring only 10% of its operating costs to be subsidized through government funds, compared to 28% for Germany as a whole and 65% in the USA (APTA, 2006, RVG, 2008c, VDV, 2008). It is not possible to provide Freiburg's ratings on all the sustainability indicators listed in Table 2, but the available statistics are consistent with Freiburg's image of being a very sustainable city.

A key aspect of Freiburg's sustainability is the dramatic shift in travel behaviour between 1982 and 2007. As shown in Figure 1, the car share of trips in Freiburg fell from 38% to 32% during a period in which the car's mode share was increasing rapidly almost everywhere else in the world (Bratzel, 2000, University of Dortmund, 2001, City of Freiburg, 2008f). At the same time, the bike share of trips in Freiburg almost doubled, from 15% to 27%, and the public transport mode share trips rose from 11% to 18%.

While the car share of trips in Freiburg is only half that for Germany as a whole, Freiburg's bike share is three times as high, and its public transport share is twice as high. Freiburgers average 339 public transport trips per year, four times as many as the average German (84 trips) and 15 times more than the average American (22 trips) (BMVBS, 2004, ORNL, 2005, City of Freiburg, 2008f). Freiburgers average 350 bike trips per year, three times as many as the average German (104 trips) and 29 times more than the average American (12 trips). Differences in walking rates are smaller. Freiburgers walk only about 10% more than other Germans (299 vs. 269 trips per year) but 137% more than Americans (299 vs. 126 trips). Freiburg has avoided car dependence by providing a full spectrum of travel options that offer a genuine choice in ways to get around.

The trends away from car use, as documented above, did not result from a sudden impoverishment of Freiburg. On the contrary, employment in Freiburg grew at three times the overall German rate from 1996 to 2005 (11% vs. 4%) (INKAR, 2005). In 2005, per-capita income in Freiburg was 29% higher than for Germany as a whole (€35,200 vs. €27,200). Freiburg's economy has profited from its increasing focus on sustainability. Since the early 1980s, Freiburg has fostered the development of its environmental, solar, and biotechnology industries. By 2007 Freiburg had become Germany's leader in the area of green industries, with 1,500 companies employing roughly 10,000 people and contributing approximately €500 million to the local economy (City of Freiburg, 2009a). Moreover, Freiburg's tourist industry has boomed thanks to a doubling in the number of tourists since 1995 (City of Freiburg 2009b). Thus, Freiburg has actually profited from its increasing focus on sustainability.

Figure 1: Percentage of Trips by Mode of Transport in Freiburg, 1982-2007



Sources: Pucher and Clorer (1992), University of Dortmund (2001), Gutzmer (2006) City of Freiburg (2008g)

A flourishing economy and high per capita incomes do not necessarily require high levels of car ownership and use. Rising incomes in Freiburg did not stimulate the demand for cars nearly as much as the demand for environmental protection and overall quality of life. That provided widespread public and political support for the policy measures implemented in Freiburg since 1970 that have restricted car use while promoting public transport, cycling, and walking. The rest of this paper examines Freiburg's transport, land use, and housing policy reforms that account for its turnaround in travel behavior and sustainability gains.

4.3. Evolution of land use and transport policie. Freiburg was almost completely destroyed in World War II. In 1948, the city adopted a reconstruction plan to rebuild the city centre in its old, compact form instead of adopting a modern, car-oriented urban structure (Pucher and Clorer, 1992, City of Freiburg, 2008c). During the 1950s and 1960s, however, Freiburg grew rapidly, with the construction of new neighbourhoods on the fringe of the city, especially toward the Rhine River Plain to

the west, where the terrain is flatter. The new residential and industrial districts were more spread out and more car-oriented than the historic town centre, with wider streets, a more regular street pattern, and more parking facilities. During this period, car ownership and use grew rapidly, causing increased air pollution, congestion, and traffic injuries (Pucher and Clorer, 1992, Gutzmer, 2006, City of Freiburg, 2008c). The city's response was to widen roads and build several new arterial roads, including one that connected the town centre with the autobahn. Many tram lines were abandoned in favour of bus services (Nahverkehr Breisgau, 2008). City land use plans gave top priority to increasing the supply of housing by expanding into previously undeveloped areas. Transport plans focused on the need to accommodate increasing car use, even in the historic city centre, where the main town square was used for car parking (City of Freiburg, 2008c).

In the late 1960s and early 1970s, transport and land use policies in Freiburg began a dramatic shift away from the car. The various social and environmental problems caused by car use—combined with the 1973 oil crisis—evoked a grassroots revolt among the citizens of Freiburg, forcing politicians to adopt a series of crucial policy decisions. The city adopted new plans to restore, expand, and modernize the tramway, to establish an integrated network of separate bicycling facilities, and to turn most of the historic old town into a pedestrian zone off limits to cars. Freiburg's first intermodal transport plan of 1972 emphasized the importance of walking, cycling and public transport for the overall transport system, and the 1979 update of the transport plan explicitly called for favouring those 'green modes' over the car. The 1989 transport plan went a step further by endorsing the overall reduction of car use by restricting car use in the city centre and all residential neighbourhoods.

As transport policies in the 1970s and 1980s increasingly restricted car use and favoured the green modes, land use policies shifted accordingly. In particular, new development was to be concentrated along public transport corridors, especially the city's expanding light rail public transport system, the Stadtbahn (City of Freiburg, 2008c). The most recent land use plan of 2008 reiterates the earlier goals of reducing car use but is more explicit about prohibiting car-dependent developments and even supports car-free neighbourhoods. The plan focuses on high-density development along light rail routes, strengthening local neighbourhood commercial and service centres, and mixing housing with stores, restaurants, offices, schools, and other non-residential land use uses (City of Freiburg, 2008c). Central development is explicitly favoured over peripheral development on the suburban fringe. The city has banned all car-dependent big-box retailers such as home improvement stores, furniture stores, and gardening centres, not only because of the car traffic they generate but also because they draw customers away from central city and neighbourhood retailers.

All future development is to be based on the principle of shortening trip distances to make them more walkable and bikeable, ensuring local accessibility to all the daily necessities of life. The 2008 land use plan further strengthens the priority given to public transport, walking, and cycling over the car. More generally, it adopts the goal of preserving the historical character of the

city and increasing the quality of life and overall attractiveness of Freiburg as a place of residence, employment and tourism.

Photo 1a: Freiburg's Cathedral Square was used as a car park in the 1960s.
Source: City of Freiburg

Photo 1b: During the mid 1970s, cars were banned from Freiburg's Cathedral Square. It is now a lively pedestrian zone with an open-air market.
Source: City of Freiburg

There are two recent examples of the complete coordination of transport with land use in Freiburg. Rieselfeld and Vauban are residential developments built from 1993 to 2009 around newly extended light rail lines (Ryan and Thorgmorton, 2003, City of Freiburg, 2007b, 2008e). Both sharply limit car access and parking. All streets are traffic calmed at 30 km/hr or less. Many streets are designated as home zones, with speed limits set at 7km/hr and traffic priority for pedestrians, cyclists, and playing children. Both communities feature high density and the mixing of residential, commercial, educational, religious, and recreational land uses. They provide a wide range of housing types for low-income as well as affluent households and specifically favour inclusion of women, families, the elderly, and persons with disabilities. Rieselfeld and Vauban feature high quality green spaces, low energy construction methods, solar energy, and rain water re-use (Ryan and Thorgmorton, 2003, City of Freiburg, 2007b, 2008e). The residents of Vauban convinced the city government to go one step further and to accommodate car-free living, banning cars from residential streets altogether and restricting parking facilities to the periphery of the community.

Photo 2a: Klarastrasse in the 1960s. A Street designed for cars, not for people.
Source: City of Freiburg

Photo 2b: Klarastrasse after traffic calming. Today, it is a street that limits car use and thus enhances safety, quiet, and neighbourhood quality of life.
Source: City of Freiburg

Freiburg's transport and land use plans were coordinated with federal, state, and regional transport and land use plans, with the plans of adjacent municipalities, and with local and regional public transport plans (City of Freiburg, 2008c, f). They were developed with extensive citizen participation at every stage and reflect widespread support for environmental protection. As documented in the following sections, the complete turnaround in Freiburg's transport policies resulted in dramatic improvements for public transport, bicycling, and walking, while making car use more expensive, slower, and less convenient.

4.4. Public transport improvements

Freiburg's Stadtbahn, its light rail system, has been the centrepiece of the city's multi-faceted strategy to improve overall transport sustainability. Although a few old streetcar lines were still operating in the 1970s, they were slow and outdated. Construction of the first modern light rail line started in 1978 and was completed in 1983. The Stadtbahn system has since expanded to four lines with a total extent of 36.4 km in 2008 (City of Freiburg, 2009b). From 1983 to 2007, the total supply of light rail service almost tripled, rising from 1.1 to 3.2 million vehicle km (Figure 2). The light rail lines focus radially on the city centre and terminate in various inner suburbs (City of Freiburg, 2009b). Most of Freiburg's population now lives and works within easy walking distance (300 meters) of a light rail line: 65% of

residents and 70% of all jobs (City of Freiburg, 2008f). With further expansions planned, the city's goal is to raise those percentages to 83% of residents and 89% of jobs.

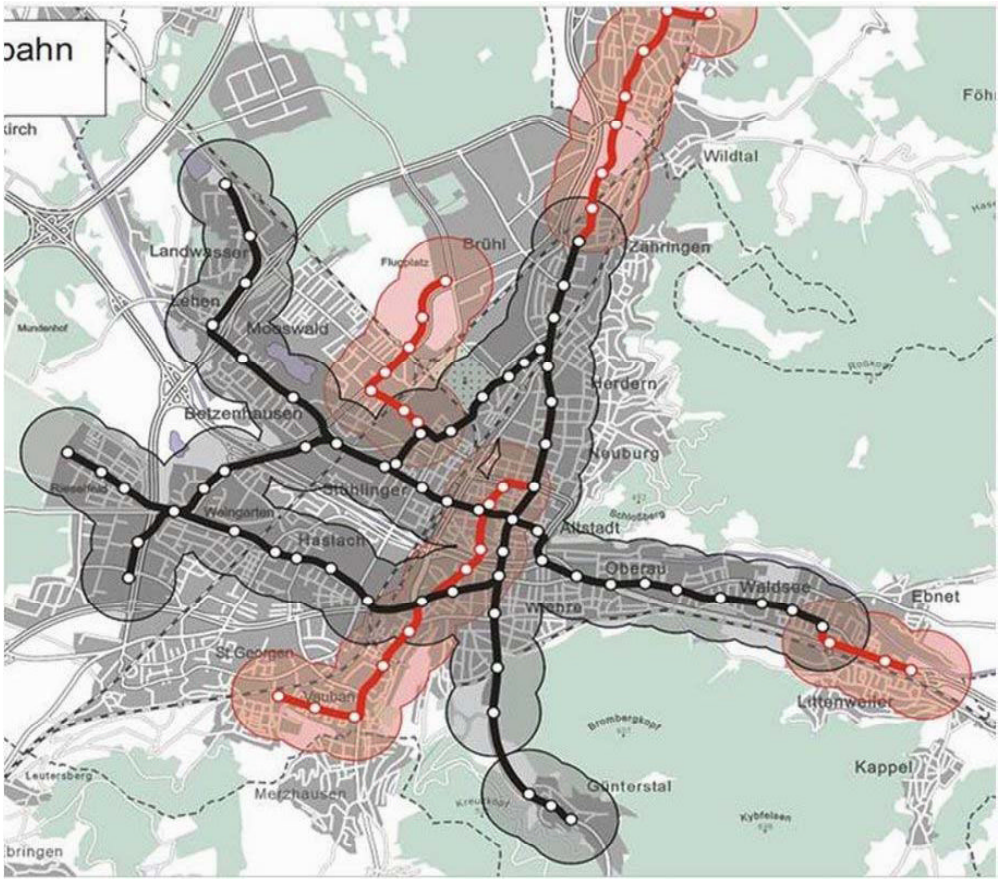
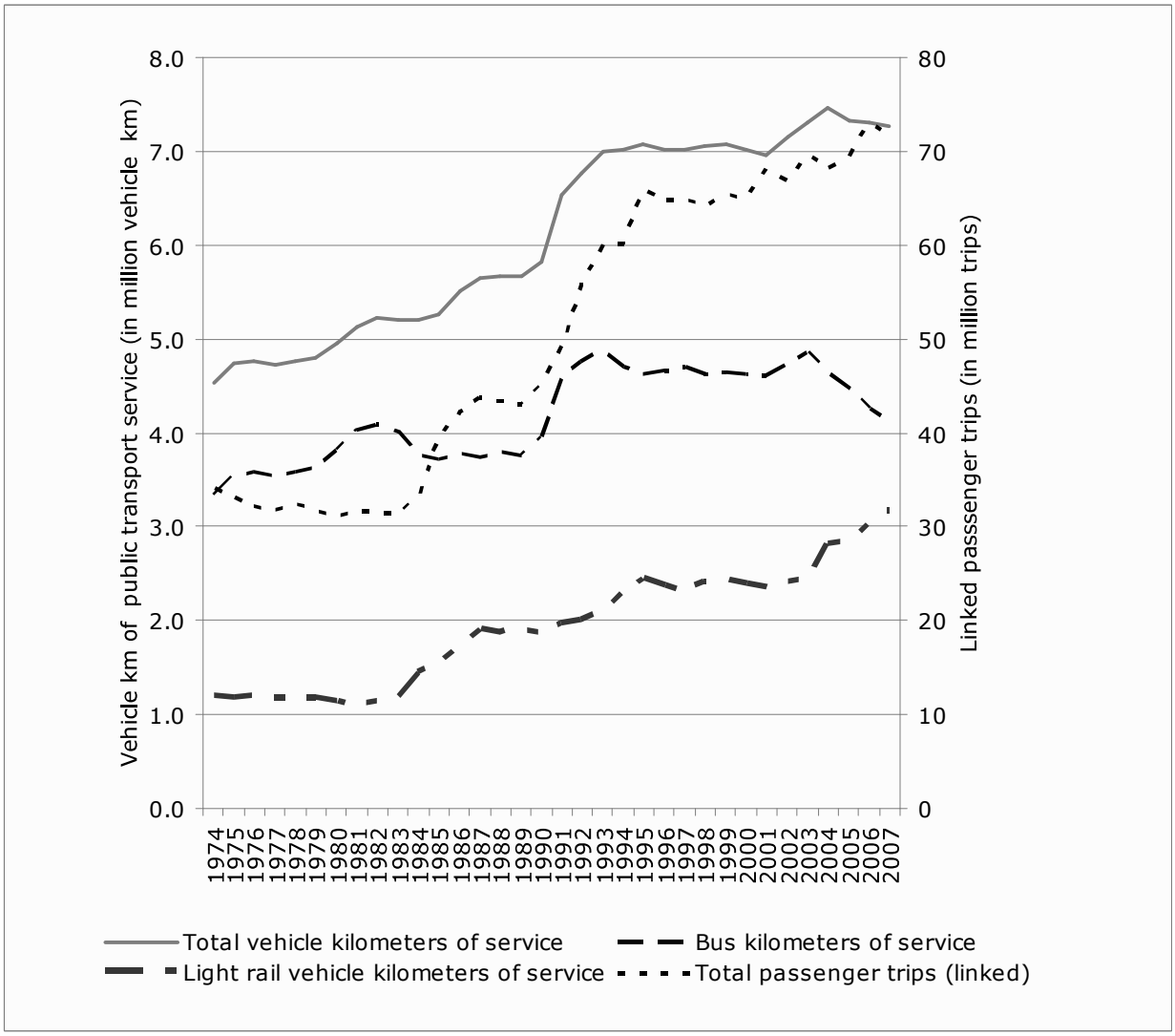


Photo 3: Most Freiburgers live and work within 300m of a light rail stop (grey and red shaded areas).
Source: City of Freiburg

The extent of the bus system has also expanded: from 100 route km in 1974 to 273 route km in 2007 (City of Freiburg, 2009b). Over most of that period, vehicle km of bus services increased, but since 2003 bus services have been cut back as high-volume bus lines are replaced with light rail lines (ZRF, 2003, City of Freiburg, 2009b). The new policy has been to use buses as a feeder mode to bring passengers from outlying neighbourhoods to light rail, which then carries passengers to the city centre. As of 2006, light rail carried 70% of all passenger trips in Freiburg, compared to 30% on buses (Gutzmer, 2006).

Figure 2: Trends in Public Transport Supply and Demand in Freiburg, 1974-2007



(Note: public transport demand reported as linked passenger trips; passengers switching between lines and modes were only counted once)
Source: City of Freiburg (2009b)

As shown in Figure 2, total public transport use in Freiburg fell between 1974 and 1983 (from 34 to 31 million trips), in spite of a considerable increase in bus services. Since the opening of the light rail system in 1983, however, public transport use has risen sharply (City of Freiburg, 2009b). Public transport trips roughly doubled between 1983 and 2007 (from 31 to 72 million passenger trips). Freiburgers average 339 public transport trips per year, or about one per day for each resident. It is the highest rate of public transport use of any German city and four times as high as the German average of 84 (VDV, 2008, City of Freiburg, 2009b).

Freiburg's light rail trains run at intervals of 7.5 minutes or less (Gutzmer, 2006, City of Freiburg, 2008f). They are fully integrated with the city's 26 bus lines, which run every 15 minutes near the centre and every 20 to 30 minutes in outlying areas. Both light rail and buses

in Freiburg benefit from traffic signal priority, with lights turning green for oncoming trams and buses at key intersections. That increases overall public transport speeds. In addition, real-time information is provided on digital displays at light rail stops and key bus stops (ZRF, 2003, City of Freiburg, 2008f, ZRF, 2008).

Photo 4: Freiburg's light rail lines converge in the pedestrian zone, which encompasses the entire city centre. Modern, low floor vehicles, traffic signal priority, and real time information make public transport a convenient, fast and reliable travel option.
Source: John Pucher

The extensive suburban rail and bus services throughout the region are centred on Freiburg and have grown rapidly over the last two decades. Between 1991 and 2005, regional public transport service increased by 24% (from 2.7 billion to 3.4 billion seat kilometers) (ZRF, 2008). Rail services, in particular, have been growing rapidly in recent years, and passenger km of regional rail use rose 6-fold between 1997 and 2006: from 5 million to 31

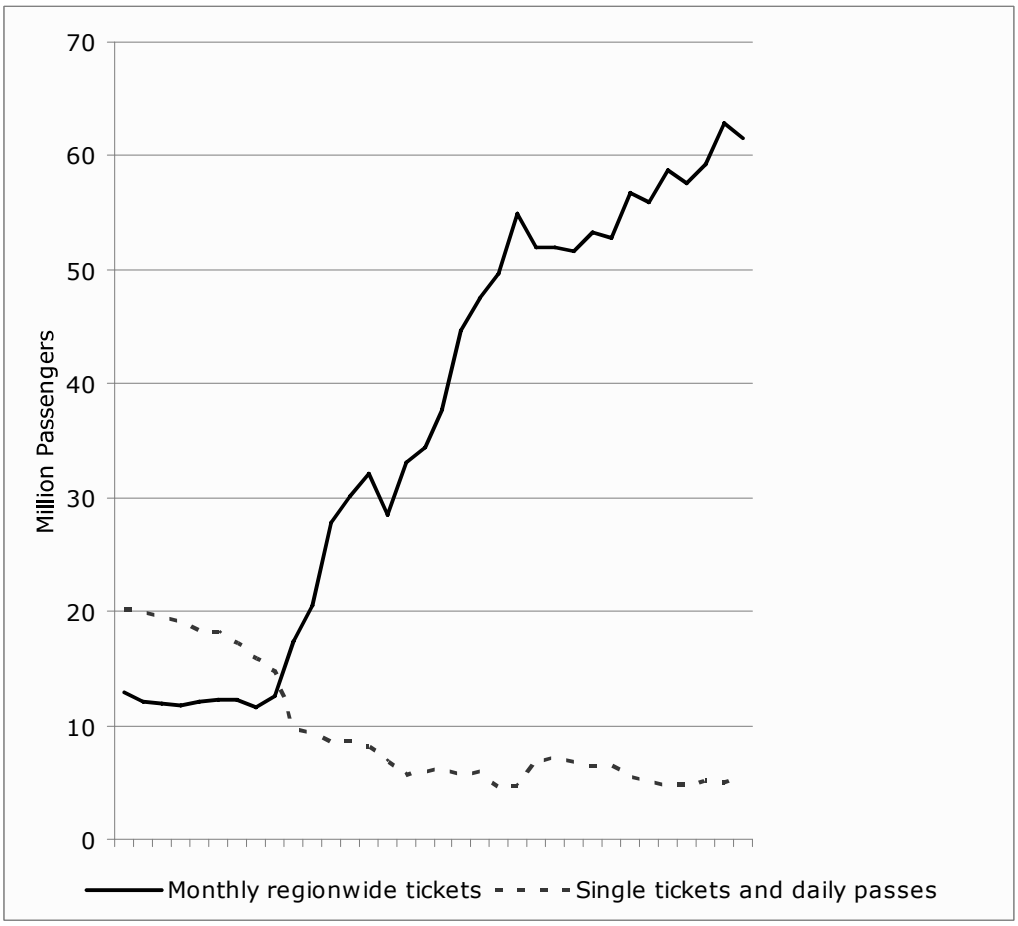
million (ZRF, 2008). Bus services have expanded as well, especially those connecting small towns and villages to regional train stops. Including all public transport services in the city of Freiburg and the surrounding region, demand grew from 57 million trips in 1985 to 109 million trips in 2007, an increase of 89% (RVG, 2008a).

Services, fares, and subsidies for the entire Freiburg region are coordinated by the Zweckverbund Regio-Nahverkehr Freiburg (ZRF), a regional public transport association that includes 187 different bus and rail operators, 90 different lines, and 3050km of routes (RVG, 2008e, g, ZRF, 2008). ZRF serves 625,000 residents in three counties and 75 towns. ZRF sets overall public transport policy in the region and develops an updated public transport plan every five years. It is also responsible for receiving funding from federal, state and local governments and then distributing those funds among the 17 public transport operators to cover investment and operating expenses.

A key aspect of this multi-modal, multi-agency regional coordination is the unified ticketing system, which enables riders to use a single ticket for several trip segments and different types of service. In 1984, Freiburg's VAG public transport system offered Germany's first monthly ticket transferable to other users (Bratzel, 1999, Hilliard, 2006). It was marketed as the 'environmental ticket' (Umweltschutzkarte) to emphasize the environmental advantages of public transport over the private car. In 1991, a region-wide ticket, the RegioKarte, greatly expanded the geographic region covered by the monthly ticket from 153km^2 to 2211km^2 (ZRF, 2008). These monthly tickets have offered bargain fares for regular public transport users (Gutzmer, 2006, RVF, 2006). In 2008 the monthly RegioKarte cost only €45.50, and the annual RegioKarte cost €455 (or €37.92 per month) for unlimited travel within the entire ZRF region. Students can purchase either the discounted €33.50 RegioKarte or the even cheaper Semester Ticket for six months, which costs €69 (or €11.50 per month) (VAG, 2009). For €9.90 a day, holders of the Freiburg RegioKarte can purchase additional unlimited travel throughout the five regional public transport regions immediately adjacent to the ZRF, increasing their travel area to 7235 km^2 (RVF, 2006, RVG, 2008f). Yet another innovation is the RegioMobilKarte, which costs only €47 per month and provides all the benefits of the regular RegioKarte plus car-sharing membership, reduced taxi fares, and discounts on bike and car rentals.

The Umweltschutzkarte introduced in 1984 contributed to the 12% increase in riders between 1984 and 1990, but the RegioKarte introduced in 1991 had an even greater impact (RVG, 2008b). Total public transport trips in the entire ZRF region increased by 70% between 1990 and 2007 (Gutzmer, 2006, RVG, 2008b). Another indicator of the popularity of the monthly cards is that a growing percentage of public transport riders purchase these monthly tickets. As shown in Figure 3, over 60 million of the trips within the city of Freiburg itself relied on the monthly pass in 2007, compared to only 6 million using single tickets or daily passes (City of Freiburg, 2009b). Similarly, 90% of passengers in the entire ZRF region rode with monthly passes in 2005 (RVF, 2006, RVG, 2008d).

Figure 3: Trend toward monthly region-wide tickets in Freiburg, 1974-2007



Sources: City of Freiburg (2009b)

A specific example shows how well public transport competes with the private car, both in terms of cost and time. In 2006, a typical commute from the suburban town of Emmendingen to Freiburg's town centre took 40 minutes by car and 44 minutes by public transport (including walk trips to access stops) (RVF, 2006). With an annual ZRF RegioKarte, the average commuter paid €430 a year. That was only 60% of the annual cost of petrol (€740) for same commute by car, and only 30% of the total annual cost of owning a car and driving daily between Emmendingen and Freiburg (€1570) (RVF, 2006).

One might assume that the massive improvement of Freiburg's public transport system and its extraordinarily inexpensive fare options would have greatly added to government subsidy requirements. On the contrary, the operating subsidy per passenger trip (in constant 2007 Euros) fell from €1.07 in 1984 to only €0.08 in 2007 (Gutzmer, 2006, RVG, 2008c). Currently, Freiburg's public transport system covers 75% of its operating costs from passenger fares, 15% from state government reimbursements for student and elderly reduced fares, and only 10% from direct operating subsidy from the City of

Freiburg, the two adjacent counties, and the state government (RVF, 2008).

There are two explanations for the sharp drop in operating subsidy requirements: reduced costs and increased revenue. According to Freiburg's public transport planners, operating costs per vehicle km of service have been reduced by better coordinating and rationalizing services among all providers, purchasing larger and newer vehicles, and hiring more part-time labour (RVF, 2006, Hildebrandt, 2009). With fuller integration of services, duplicative routes have been eliminated. The fleet of buses and trams has been modernized, thus increasing reliability as well as reducing maintenance costs. Freiburg has opted for articulated buses and trams, which require fewer drivers per passenger. Labour costs have also been reduced by hiring more part-time workers, who can help provide extra service during peak hours. Finally, automatic signal priority at intersections speeds up buses and trams, increasing the vehicle km of service that any given driver can produce.

In Germany as a whole, total labour costs for public transport fell by 10% from 1997 to 2006 (VDV, 2008). Over the same period, the number of full-time employees fell by 26%, while the number of part-time employees rose. Since part-time workers are not paid for a full day, they make it less expensive to provide more frequent service during peak hours (VDV, 2008). There has also been increasing competition among public transport operators, as mandated by the EU regulations that require tendering of all services in an EU-wide market (VDV, 2008). Most regional bus services are already run by private operators, who compete for service contracts and receive no operating subsidy at all. City bus and light rail services and suburban rail services have been streamlining their operations in preparation for competitive service tendering in the coming years.

As costs have fallen, revenues have risen. The doubling of public transport use in Freiburg and its surrounding region has increased the number of passengers per vehicle and thus passenger revenue per vehicle mile of service. That suggests that the demand for public transport is elastic in Freiburg, perhaps due to the many severe restrictions on car use and parking as well as the high cost of owning, driving, and parking a car. As car use is made more expensive, slower, and less convenient, public transport obviously becomes a more attractive substitute for the car. Inexpensive monthly passes in Freiburg have an especially large impact on usage because the time and convenience of public transport services are comparable to those of car use, or even better in some instances. That is confirmed by the previous example of the work commute between Emmendingen and Freiburg.

In Germany, capital investments in public transport are covered primarily by federal and state funds (Rönnau *et al.*, 2002, Scholz, 2006). There are many programs and sources of funds depending on the specific type of capital investment. That makes identifying exact funding streams difficult (Scholz, 2006). Neither state nor local government officials have comprehensive data on capital financing for public transport in the Freiburg region.

Even within a single capital project, funding responsibilities and sources can vary between local, state and federal governments. For example, the ZRF estimates that planning and construction costs for the "Breisgau S-Bahn" regional rail expansion will be €400 million

between 1997 and 2018. Federal and state governments will cover 75% of construction costs. Local governments will fund the remaining 25% of construction costs and pay all planning costs. Overall, state and federal subsidies will cover 60% of project costs (RVG, 2008e, g, ZRF, 2008).

Capital investments for the expansion of Freiburg's light rail network averaged €16 million per year from 2000 to 2007 (Hildebrandt, 2009). According to local transport planners, three further extensions planned for the coming years will require significant increases in funding.

In summary, the total government investment in regional public transport has been large in Freiburg, but it has enabled a significant increase in the quantity and quality of public transport services in Freiburg and its surrounding region. Moreover, operating subsidies have fallen sharply, suggesting that Freiburg's long term investments have paid off financially. Not only has total public transport use increased, but its share of overall travel has also increased. These are impressive accomplishments, even relative to the overall German context of successful public transport.

4.5. Bicycling and walkin. Bicycling has flourished in Freiburg over the past few decades. The total number of bike trips rose from 69,500 in 1976 to 211,000 in 2007, nearly tripling (Pucher and Clorer, 1992, University of Dortmund, 2001, City of Freiburg, 2008f). From 1982 to 2007, the bike share of trips increased from 11% to 28%, the second highest of all German cities, exceeded only by Muenster, which has a bike share of 35% (Pucher and Buehler, 2008). As in most German cities, the share of trips by foot in Freiburg has fallen considerably in recent decades, mainly due to lengthening trip distances as cities have been spreading out. The decline in walking was most pronounced in the 1980s, with the walk share of trips falling from 35% in 1982 to 24%, apparently due to a shift from walking to cycling and public transport. Since 1982, however, the walk share has remained stable and was 23% in both 1999 and 2007.

Although Freiburg seeks to promote both cycling and walking, most of its efforts have focused on cycling. The city expanded its network of separate bike paths and lanes from only 29km in 1972 to 160km in 2007 (FitzRoy and Smith, 1998, City of Freiburg, 2008a). In addition, the cycling network includes 120km of bike paths through forests and agricultural areas, 400km of traffic calmed roads, and 2km of bicycling streets, where cyclists have absolute traffic priority (City of Freiburg, 2008b). In total, there were 682km of bike routes in 2007, and they continue to expand. Perhaps most important, Freiburg's cycling facilities have been fully integrated into a complete bikeway network that permits cyclists to ride on separate facilities or safe, lightly travelled streets between virtually any two points in the city.

The traffic calming of residential neighbourhoods has turned almost all residential streets into good bike routes. Roughly 90% of all Freiburg inhabitants live on the 400km of streets where the speed limit is 30km/hr or less (City of Freiburg, 2008f). Moreover, in 2008 there were 177 home zones, where the speed limit is further reduced to 7km/hr, and cyclists and pedestrians have strict priority over cars (City of Freiburg, 2008f, 2009a).

In addition, about half of the 120 one-way streets in Freiburg are 'falsche Einbahnstrassen,' where cyclists can ride in either direction, while motorists are restricted to one (City of Freiburg, 2008a)

Photo 5a: The Wiwili Bridge in Freiburg ca. 1970. Both lanes were reserved for motor vehicles. The former tram line crossing this bridge was removed in the 1960s.
Source: City of Freiburg

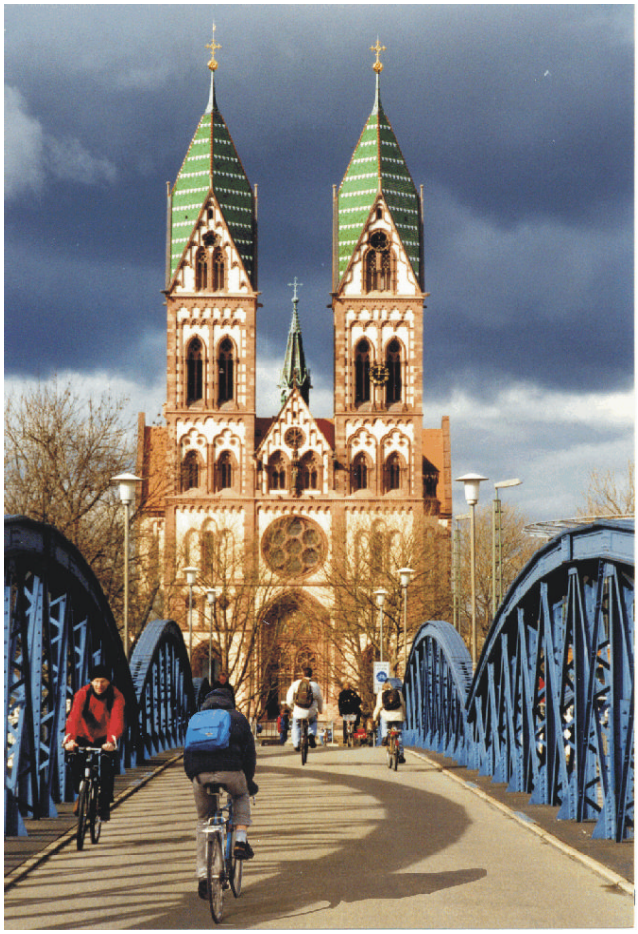


Photo 5b: The Wiwili Bridge today. With motor vehicles banned from the bridge, bicycles have the right of way over the entire width of the roadway. Not visible in this photo, there are pedestrian footpaths to the right and left of the blue steel barriers.
Source: City of Freiburg

Photo 6: Woman cycling in one of Freiburg's 177 home zones, where cars are required to drive at "walking speed" (<7km/hr). German implementation of home zones (Spielstrassen) requires minimal changes to street design and thus are inexpensive.
Source: City of Freiburg

Photo 7: All residential streets in Freiburg are traffic calmed, with a speed limit of 30km/hr or less. This is one of Freiburg's 177 home zones, where the speed limit is further reduced to 7km/hr in order to permit walking, cycling and playing on the street.
Source: City of Freiburg

Over the past three decades, the city has been increasing the supply of bike parking, improving its quality, and integrating it with public transport stops. Between 1987 and 2009, the number of bike parking spaces almost tripled, rising from 2,200 to 6,040 (Gutzmer, 2006, City of Freiburg, 2008f, a). There are now 1,678 bike parking spots at public

transport bike and ride facilities, including 821 sheltered bike racks and 23 secure bike lockers. In addition, there is a major bike station at Freiburg's main train station offering secure, sheltered parking for 1,000 bikes (for €1 per day or €10 per month), bike rental, bike repair, travel advice, and bike shipment to other cities (City of Freiburg, 2008a). Not only does the city provide bike parking directly, but it also requires all new buildings with two or more apartments to provide accessible bike parking (City of Freiburg, 2008d). Building codes require varying amounts of bike parking for schools, universities, businesses, and stores.

The city's three most important approaches to improving walking conditions are car-free zones, traffic calming, and new developments that generate short, walkable trips (City of Freiburg, 2008c). Freiburg was the first German city to create an interconnecting network of car-free streets in its city centre in the early 1970s (Beatley, 2000). The pedestrian zone already covers the entire historic old town and will soon be extended by about 0.5km westward to the main train station, permitting a safe, car-free walking environment between the station and the city centre (City of Freiburg, 2008f).

Photo 8: Interior view of the bike parking garage at Freiburg's main train station, which holds 1,000 bikes and offers bike repairs, bike rentals, and bike touring advice.
Source: Ralph Buehler

Almost all of Freiburg's residential streets are already traffic calmed at 30km/hr or less, and the recent trend has been toward home zones, which further reduce speed limits to 7km/hr. As shown by several academic studies, traffic calming encourages more walking and makes it

safer (Herrstedt, 1992, Webster and Mackie, 1996, Morrison *et al.*, 2003, Tolley, 2003). As described earlier, the city is working to develop more neighbourhoods with a mix of residential, commercial, educational, and recreational facilities so that more trips are short and walkable.

Photo 9: Rathausgasse, part of the extensive car-free pedestrian zone in Freiburg's historic centre. The entire city centre was rebuilt in its historic form after almost complete destruction during WWII.
Source: Ralph Buehler

Freiburg transport planners concede that more needs to be done to encourage more walking (City of Freiburg, 2008f). Some of the new cycling and tramway infrastructure, for example, narrowed pedestrian walkways. The latest plans call for widening some sidewalks as well as improving pedestrian crossings and lengthening the crossing time for pedestrians at signalized intersections. Expansion of Freiburg's pedestrian zone, further implementation of home zones, and mixed-use developments should also promote more walking.

Although Freiburg has ambitious plans for further improving conditions for cycling and walking, it has already achieved a great deal. It has one of the highest non-motorised mode shares in Germany: 50% of all trips were by walking or cycling in 2007.

4.6. Restrictions on car use. Many of the previously discussed measures to promote public transport, bicycling, and walking involve restrictions on car use. Car-free zones and traffic calming are perhaps the most obvious examples. Signal priority for buses, trams, and cyclists also slows down car travel. Even zebra crosswalks restrict motorists who are required to stop for pedestrians.

Since the 1970s, Freiburg has reconfigured its overall roadway network to divert through car and truck traffic onto arterials that bypass residential neighbourhoods as well as the historic centre (City of Freiburg, 2008f). Several key thoroughfares have been either widened or improved in various ways to increase their carrying capacity. Freiburg combines disincentives to car use in the town centre and residential neighbourhoods with improvements in key roadways that actually benefited car users. In this respect as well, Freiburg has carefully balanced the 'stick' and 'carrot' approaches in designing its transport policies (Gutzmer, 2006).

Parking policy is a key aspect of Freiburg's taming of the car (Blatter, 1995). Parking garages are deliberately placed at the periphery of the city centre, thus forcing motorists to walk or take public transport for the remainder of their journeys. In many residential neighbourhoods, parking is reserved for residents only and requires a special permit. On-street parking in commercial areas of the city becomes more expensive with proximity to the centre: €2.20 in the innermost zone, €1.60 in the intermediate zone, and €.60 in the outermost zone (City of Freiburg, 2006, 2008f). Almost all on-street car parking is limited in duration to prevent long-term parking by commuters. Building codes have reduced parking requirements for cars in new residential developments at the same time they increased parking requirements for bikes. As noted earlier, Rieselfeld and Vauban restrict most car parking to the edge of their neighbourhoods in order to prevent the incursion of cars (City of Freiburg, 2008e).

All of these car-restrictive measures implemented at the local level are reinforced by the high taxes and fees levied by the German federal government on car ownership and use, as documented in the first section of this paper. Together, they make car use more expensive, less convenient, and slower than it would otherwise be. That obviously enhances the relative attractiveness of public transport, walking, and cycling. It is the combination of car-restrictive measures with improvements in public transport, walking, and cycling that explains the success of Freiburg in actually reducing car use over recent decades.

5. Conclusions and lessons from Germany. Transport and land use policies help explain the sustainability of urban passenger transport in Germany. In spite of per capita income and car ownership rates that are among the highest in the world, German governments at every level have explicitly encouraged compact, mixed-use developments with excellent facilities for walking and cycling. Similarly, for many decades German public policies have consistently promoted public transport services that are extensive, frequent, convenient, and attractively priced, thus providing a feasible alternative to the car for many trips. At the same time, a wide range of policies in Germany has made car use more expensive and less convenient than in the USA. It is the combination of these policy carrots and sticks that perhaps best explains the greater sustainability of urban transport in Germany. The case study of Freiburg shows how to make urban transport more sustainable:

- Transport policies must be fully integrated across modes of transport and coordinated with land use policies aimed at discouraging car-dependent sprawl.
- Public transport systems must provide integrated, dependable, and convenient services that are priced attractively through discounted region-wide monthly and annual tickets.
- Politicians must garner public support by implementing controversial policies in stages over an extended period.
- Policies must fully integrate public transport, walking and cycling to foster the synergies of these complementary modes of sustainable transport.

- Urban planners and government officials must effectively communicate the benefits of sustainable transport, emphasizing the wide range of economic, environmental and social advantages to everyone.
- Land use and transport policies must be coordinated by planning for compact, mixed-use development that clusters residents and businesses near public transport services and generates a high proportion of trips short enough to cover by walking or cycling.
- Policies must restrict car use and make it less convenient, slower, and more expensive, especially in centre cities and residential neighbourhoods.

Some of the policy measures adopted in Freiburg and in Germany may seem impossible in car-oriented countries like the USA, Australia, and Canada. However, they are likely to become politically feasible as transport problems such as congestion, pollution, energy use, and climate change get so bad that the majority of voters, and the politicians they elect, are finally willing to do something about them. Even now, there appears to be increasing public awareness and political support for energy conservation, environmental protection, congestion relief, traffic safety, financial viability, mobility options, and social equity. There is a growing realization that everyone would benefit from more sustainable transport, and that enhances the political acceptability of the measures needed.

Sudden crises, like the sharp rise in petrol prices in 2008, should be a wake-up call, dramatically demonstrating the importance of sustainable transport system. Many American families, for example, were not able to shift to alternative modes of transport and had to spend an even higher share of their household budget on daily travel. Car-dependence makes transport systems vulnerable to changes in resource availability, threatening the long-term economic viability of cities and countries.

By comparison, a transport system with a wide range of travel options, as in Germany, is far more resilient (Newman et al., 2009). Freiburg is a perfect example of a city that is already implementing the measures necessary to adapt to a future with severe resource constraints. The story of its success should be a hopeful and reassuring, showing that a city can flourish by adopting a wide range of sustainable land use, housing, and transport policies. Becoming more sustainable should not be viewed as a burden but rather an opportunity to enhance the mobility of everyone while preserving the environment, conserving natural resources, mitigating social problems, saving money, and even stimulating the economy. One need only visit Freiburg to experience the advantages of sustainability.

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