TRANSPORT POLICIES, TRAVEL BEHAVIOR, AND SUSTAINABILITY: A

COMPARISON OF GERMANY AND THE U.S.

by

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ABSTRACT OF THE DISSERTATION

Transport Policies, Travel Behavior, and Sustainability: A Comparison of Germany and the U.S.

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This dissertation investigates the influence of transport policies on individual travel behavior in Germany and the U.S. In spite of increasing automobile use in both countries, Germany has been more successful than the U.S. in maintaining a more balanced, sustainable transport system. In 2002, Americans drove 125 percent more kilometers per capita than Germans. Walking, cycling, and public transport accounted for only 14 percent of all trips in the U.S., compared to 40 percent in Germany. Excessive reliance on the car is responsible for unsustainable trends such as environmental pollution, oil dependence, obesity, traffic congestion, and road fatalities. In 2005, urban transport energy use and CO_2 emissions per capita were three times higher in the U.S. than in Germany.

This analysis contains two parts capturing the interdependencies of transportation policies and individual travel decisions. A descriptive and qualitative examination of differences in travel trends and transport policies over time sets the frameworks within

which individuals make daily travel choices in each country. A multivariate analysis based on two comparable national travel surveys then explores the intricacies of these choices.

The analysis shows that policies and institutions in the U.S. contribute to making car use cheaper, easier, and more common than in Germany. In 2005, for example, revenues from roadway user taxes and fees in Germany were 2.6 times larger than roadway expenditures by all levels of government, compared to net subsidies for roadways in the U.S. Unlike the majority of American cities, most German municipalities promote non-automobile travel and impose restrictions on driving, thus making car travel slower and less attractive. In 2002, average car travel speeds in the U.S. were 33 percent faster than in Germany. Multivariate analyses showed that transportation policies accounted for up to 25 percent of the variability explained in travel behavior.

Several policy recommendations follow from this research. First, higher population density, a greater mix of land uses, access to public transportation, and higher gasoline prices reduce car travel. Second, higher car-ownership rates and faster average car travel speeds increase car use. Lastly, the combination of car-restrictive policies with measures that increase the attractiveness of non-automobile modes has been key to more limited car use in Germany.

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1 Introduction

This dissertation investigates transportation policies and individual travel behavior in Germany and the United States. A better understanding of the influence of transportation policies on travel behavior in highly motorized countries may help combat unsustainable trends related to transportation, such as environmental pollution, oil dependence, obesity, traffic congestion, and road fatalities. While car ownership rates have grown rapidly in both countries over recent decades, Germany has been more successful in limiting car use and its negative externalities. For example, in 2002, Americans drove 125 percent more kilometers per capita than Germans, while Germans used transit, cycled, and walked for four times as many trips as Americans did. Moreover, the German passenger vehicle fleet was 33 percent more fuel efficient than the American fleet. As a result, transportation energy use per capita and CO_2 emissions from individual passenger road transportation were roughly three times higher in the U.S. and there were twice as many traffic fatalities per capita in the U.S. than in Germany.

In both countries, the policy framework for individual travel behavior is set through regulations, subsidies, and taxation at all levels of government. Within this framework of incentives and disincentives, individuals make choices about where to live, what mode of transportation to use, and the number and distance of their daily trips. Transportation policies and individual travel choices are directly related to the social, environmental, and economic costs of transportation. More sustainable transportation can only be achieved if transportation policies, individual travel decisions, and their interdependence are understood.

As such, this international comparative analysis is comprised of two major parts: The first is a description and qualitative examination of differences in travel trends and transportation policies over time. The second is a multivariate analysis based on two comparable individual level data sets, which were enriched with variables related to transportation policies and spatial development patterns. The interpretation of the multivariate analysis is guided by the policy framework analyzed in the first part of the dissertation. Differences in the impacts of transportation policies, spatial development patterns, socioeconomic, and demographic factors on travel behavior within and between the countries are examined.

1.1 Principle Motivation: The Increasing External Costs of the Automobile

During the 20th century, the automobile became the dominant mode of passenger transportation in all OECD countries, accounting for the majority of trips and passenger kilometers of travel (OECD, 2003-2007). In 2007, motorization and car use were on the rise all over the world. The automobile provides unprecedented levels of individual mobility and access to destinations. In almost all parts of the world, the automobile is therefore synonymous with individual liberty, freedom of movement, and economic prosperity.

For the last 60 years, most OECD countries have employed highway construction as economic development policy, with the aim of improving access, location choice, and movement for individuals, firms, and goods.[1] Consequently, highway builders, automobile manufacturers, parts suppliers, car dealerships, gas stations, automobile repair shops, and governmental and non-governmental highway planning agencies accounted

[1] There are several exceptions including Denmark, the Netherlands, and Switzerland for example.

for considerable shares of Gross Domestic Product (GDP) and employment in all OECD countries. Today, many developing countries and emerging economies try to facilitate economic growth by expanding and upgrading highway networks. However, many of these countries overlook the negative side effects of this growth strategy.

For the last 30 years the United States and Germany have been leading the world in motorization levels, highway construction, and automobile use. In terms of transportation policy, both countries were among the first in the world to experiment with limited access highways early in the 20th century, and both countries significantly expanded and upgraded their limited access national highway systems after World War II (Yago, 1984). American and German car ownership rates have consistently been among the highest in the world, reaching 776 and 556 per 1,000 population respectively in 2006—higher rates of motorization than in any other major European or North American country (EUROSTAT, 2005-2007; OECD, 2003-2007).

Since the late 1960s, if not earlier, it has become apparent that the automobile does not only provide private and public benefits, but that it also comes at a cost to society, the environment, the economy, and individuals. The unintended adverse side effects of car use include air pollution due to tail pipe emissions, traffic fatalities and injuries, traffic congestion, urban sprawl and loss of open space, obesity due to sedentary life-styles, and oil dependence.

Germany and the U.S. began mitigating these adverse impacts in the late 1960s and early 1970s, but did so through divergent policy strategies, with differing intentions, and dissimilar outcomes. Initially, the U.S. led the field in introducing air quality standards, catalytic converters, and seatbelt laws. But as of 2002, Germany has been more successful in limiting car use and mitigating the negative externalities associated with the automobile. Nonetheless, many problems still exist in both countries and the economic, environmental, and social costs of inaction threaten to escalate in the not so distant future.

First, while both countries have made progress in improving road safety over the last decades, in 2005 there were still 14.7 traffic deaths per 1,000 population in the U.S., and 6.5 deaths per 1,000 in Germany (IRTAD, 2008). This corresponded to a total of 43,443 Americans and 5,091 Germans who died in traffic accidents. Adjusting for vehicle kilometers of car travel, Germany was slightly safer: 7.8 traffic deaths per one billion vehicle kilometers of car travel compared to nine deaths per one billion vehicle kilometers of car travel in the U.S. (IRTAD, 2008).

Second, 32 percent of the U.S. population over 15 years old was considered obese in 2006 compared to 13 percent in Germany[2] (OECD, 2003-2007). This share has been increasing and has reached epidemic proportions in the U.S. One explanation for increasing obesity rates are sedentary lifestyle. Driving less and cycling and walking more could help burn more calories during daily life and help reduce obesity. While obesity rates were still lower in Germany, they have also been increasing (GBE, 2008).

Third, the Texas Transportation Institute (TTI) estimates that the cost of traffic congestion in the U.S. amounted to $78 billion in 2005. This is a large increase from the total of $15 billion in 1982 (measured in constant 2005 $). Congestion costs, as measured by TTI, are composed of 4.2 billion lost work hours and 2.9 billion gallons of wasted fuel. According to TTI, this translates to "*105 million weeks of vacation and 58*

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[2] Individuals with a body mass index (BMI) of over 30 are considered obese.

fully-loaded supertankers [of fuels]" (Texas Transportation Institute, 2005).[3] Unfortunately, comparative data for Germany do not exist.

Fourth, road transportation is largely dependent on petroleum as a fuel. Both countries are net importers of petroleum and thus are subject to fluctuations in the world market price of oil and political instabilities in oil rich regions in the world. In Germany, 72 percent of secondary demand for petroleum was from the transportation sector, compared to 68 percent in the U.S. (BMVBS, 1991-2007; ORNL, 2008). Compared to other industrial sectors, the transportation sector is uniquely dependent on petroleum: roughly 99 percent of fuels used in road transportation in both countries were petroleum based (BMVBS, 1991-2007; ORNL, 2008).

Fifth, the burning of fossil fuels in diesel and combustion engines has an adverse impact on local air quality and worldwide climate change. Over 30 percent of all CO_2 emissions in the U.S. and about 20 percent in Germany were caused by the transportation sectors (BMVBS, 1991-2007; ORNL, 2008). If CO_2 emissions were to be reduced, changes in the transportation sector would have to be part of the solution.

Lastly, car-based transportation systems also have an impact on household finances and expenditures. In 2001/2002 German households spent 14.5 percent of their disposable income on transportation, compared to 19.5 percent in the U.S. (BLS, 2000-2003; DESTATIS, 2003a). The largest share of this expenditure was related to owning, operating, and maintaining automobiles.

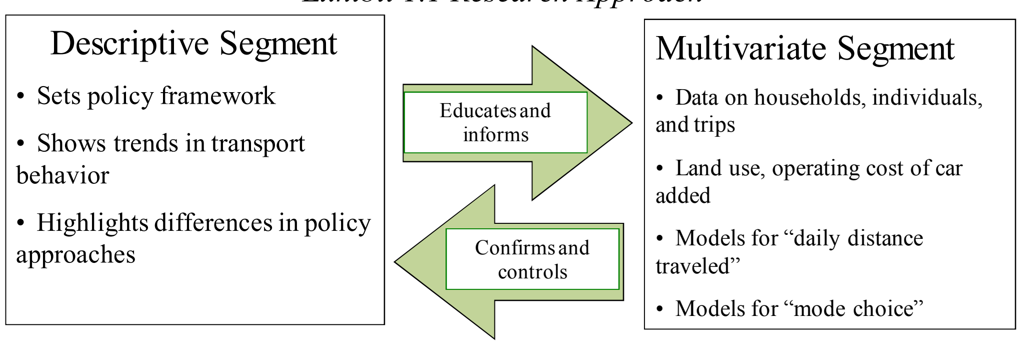
[3] TTI measures congestion as time delay relative to travel times under free-flow conditions.

1.2 Research Approach: Government Policies and Individual Travel Decisions

Governments set the policy framework for individual travel behavior through targeted transportation and other non-transportation policies. Daily transportation decisions are made by individuals within the policy and incentive frameworks. This dissertation tries to disentangle the factors influencing individual transportation decision making in Germany and the U.S., in order to better understand what types of policies are required to combat the negative externalities of passenger transportation.

Factors other than transportation policies may also help to explain individual travel behavior in both countries. These include spatial development patterns, socioeconomic and demographic factors, and culture. Differences and similarities in travel behavior are explained by a combination of these factors.

Exhibit 1.1 Research Approach



The analysis consists of two major parts (see Exhibit 1.1). First, trends over time in travel behavior in both countries are introduced. Then, similarities and differences in transportation policies affecting automobile use, public transportation, cycling, and walking are compared and analyzed. Land-use planning systems and policies are also addressed. Second, a multivariate analysis based on two uniquely comparable national household travel surveys from 2001 and 2002 highlights differences and similarities in individual travel behavior in both countries. The two datasets are enriched with variables relating to transportation policies and spatial development patterns.

The two parts of the analysis complement one another. Differences in the travel behavior of similar individuals in both countries in the years 2001/2002 are explained within their specific spatial development and transportation policy contexts. The interpretation of current travel behavior is only possible in the context of historical trends and transportation policies.

Prior international comparative studies in this field have mainly relied on aggregate level comparisons of cities and nations. The disaggregate studies that do exist were hampered by incomparability of data and data collection methods, or missing policy and spatial development variables. This dissertation is unique because it provides both a comparison of the two macro level transportation and land-use policy landscapes with trends over time, *and* adds a multivariate analysis of individual travel behavior based on two enriched micro-level datasets, which also include variables relating to transportation policy and spatial development patterns. This combination of descriptive and multivariate analyses results in a rich examination of travel behavior and its determinants in an international comparative context.

1.3 Why Compare Travel Behavior in Germany and the U.S.?

The U.S. and Germany were chosen for this analysis for several reasons. First, the two countries led the world in motorization rates and car use. From 1970 to 2006, both countries had similar growth rates of Gross Domestic Product. Today Germany and the U.S. are among the wealthiest countries in the world, with almost universal car ownership. Insights into the determinants of travel behavior and their implications for sustainability can be helpful for the development of transportation policies in other countries that face increasing motorization in the future.

Second, Germany and the U.S. have many similarities in their political systems, and are also similar in their economic prosperity and in the importance of the automobile industry for their national economies. These similarities increase the potential transferability of transportation policies, as the institutional political and economic environments of the two countries are relatively similar.

Both countries are democracies with federal systems of government and a history of local self government (Alterman, 1997).[4] Like the U.S. constitution, the German constitution guarantees local self-government. Local self-government in Germany has its roots in the early 19th century, when the Prussian emperor conceded some of his centralized power to cities and villages (Steinsche Staedteordnung 1808). In 1871, the German Reich was founded as a federation of independent kingdoms under the leadership of the King of Prussia. The formerly independent states were able to retain some of their local power through federal organization of the national government. The constitutions of the Weimar Republic (1918-1931) and the Federal Republic of Germany (founded in 1949) emphasized the importance of a federal system and local self-government (Leipold, 2000).

More importantly for transportation policy making, Germany and the U.S. are home to many of the largest and most successful car manufacturers in the world.[5] In both countries, the automobile and related industries constitute a considerable share of the national economy. For example, the German Association of the Automobile Industry

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[4] This was only interrupted during centralized Fascist rule in Germany between 1933 and 1945.
[5] The largest automobile makers in the two countries are Volkswagen, Porsche, BMW, Daimler, and Opel in Germany; and General Motors, Ford, and Chrysler in the U.S.

(VDA) estimates that about 14 percent of all jobs, 25 percent of tax revenues, and 20 percent of GDP in Germany were directly or indirectly related to the automobile industry[6] (VDA, 2007). In 2006, roughly 10 percent of all U.S. employment and about 10 percent of nominal U.S. Gross Domestic Product (GDP) were related to automobile manufacturing, dealerships, automobile repair, gas stations, transportation services and road construction (FHWA, 1990-2008).[7]

In both countries, lobbyists from the automobile industry are well organized and have significant influence on transportation policy making. For example, in 2006 the for-profit German Automobile Association (ADAC) had about 16 million members, representing roughly 19 percent of the German population (Die Welt, 2006). In 2007, the American Automobile Association (AAA) had more than 47 million members in the U.S. (AAA, 2007), representing almost 16 percent of all Americans. In both countries, any policy geared at limiting car use is poised to face fierce resistance and require compromises with these powerful interest groups. For the U.S., this is best illustrated by a famous quote from Charles Wilson, former chairman of General Motors, who in a Senate confirmation hearing for the Secretary of Defense in the Eisenhower Administration could not conceive of a situation where a Secretary of Defense would have to make a decision that is adverse to GM because he "*thought that what was good for our country was good for General Motors, and vice versa…. Our company is too big. It goes with the welfare of the country.*" [8]

[6] These shares do not include the road construction sectors.
[7] About 70% of all cars produced in Germany were exported in 2006 (VDA 2007). In the U.S. this was only slightly over 33% in 2004 (IRF 2007).
[8] http://www.defenselink.mil/specials/secdef_histories/bios/wilson.htm

Third, for Americans and Germans the automobile is a symbol of individual prosperity, progress, and liberty. For citizens in both countries the automobile is so closely connected to freedom, and emotional affections for the car are so strong, that any anti-car policy is perceived as government limitation of personal freedom and liberty. A good example of this connection between emotional affection, liberty, and car travel is the slogan "*Unlimited Car Travel for Free Citizens*".[9] This slogan was coined in the 1970s by the German car industry as a battle cry in the fight against any sort of cost increase or limitation of car use (FES, 2001). In both countries, politicians face an electorate that highly values automobiles.

Fourth, in contrast to many other Western European countries, most German cities were destroyed during the Second World War and could thus be adapted for automobile use while being rebuilt. This makes them more comparable to U.S. cities, which developed later than most European cities, and could thus also more easily be adapted to the automobile.

Fifth, the availability of two comparable micro level datasets provides an unprecedented opportunity for comparing individual travel behavior internationally, and for determining factors at the cross-section in the years 2001/2002. The comparability of these two datasets is unique and unprecedented.

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[9] In German: "Freie Fahrt fuer freie Buerger".

1.4 Academic and Practical Interest

The academic interest of this dissertation lies in (1) understanding the determinants of travel behavior in two comparable countries and in (2) disentangling the influence of transportation policies, spatial development patterns, socioeconomic and demographic factors, and culture on travel behavior. The findings and results of this study can also provide insights for policy makers in Germany and the U.S.

For example, policy makers and planners in the U.S. are interested in how Germany has managed to limit car use in face of increasing motorization and to promote transit, cycling, and walking as viable alternatives to the car. The integration and coordination of non-automobile modes of transportation are of special interest. In particular promoting policies towards public transportation and cycling could be transferred from Germany to the U.S. Furthermore, U.S. policy makers could profit from insights into the higher fuel efficiency of Germany's vehicle fleet. In short, the U.S. can gain insights into how Germany—in spite of high levels of car ownership and use—has managed to provide a more sustainable transportation system with more transportation alternatives for trip makers, more transit use, cycling and walking, and a more fuel efficient vehicle fleet.

For German planners and policy makers, the interest in this study is twofold. On the one hand, the U.S. serves as a "*window to the future*" for Germany. Over the past century many trends in society and lifestyle that first emerged in the U.S. were later observed in Germany. In the next 20 years mobility behavior of German retirees is expected to change considerably. A generation of retirees that was socialized before the advent of mass motorization in Germany will be replaced by a generation of retirees that grew up with the automobile. In the U.S., motorization occurred earlier than it did in Germany and was not interrupted by the devastations of WWII. Therefore, the mobility of the elderly in the U.S. today can serve as an example for Germany in the future. Second, German policy makers are interested in the potential transferability of successful U.S. policies. For example, in the 1970s and 1980s, the U.S. government imposed regulations on automobile manufacturers to achieve progressively increasing sales-weighted vehicle fuel efficiency standards—known as Corporate Average Fuel Efficiency standards (CAFE). U.S. experience with this regulatory regime can serve as an example for European policy makers, who in 2007/2008 intended to implement progressively increasing sales-weighted CO_2 emission standards for automobile manufacturers.

1.5 Overview of Findings

Germany and the U.S. have both exhibited trends toward unsustainable transportation with increasing automobile use over the last decades. This dissertation suggests that transportation policies and spatial development patterns have an important impact on individual travel choices and the negative externalities of the transportation system. If governments want to effectively mitigate the negative side effects of the current transportation system, a comprehensive and multifaceted policy and funding approach for all modes of transportation and spatial development patterns is necessary.

Policy analysis shows that both countries have long histories of government involvement in the passenger transportation sector through regulation, taxation, and subsidies. The transportation policy environments in both countries have grown along different paths historically and there are many differences in the policy choices made in the two countries. Both targeted transportation and non-transportation related policies account for the two countries' dissimilar transportation systems and travel behavior.

The major differences in transportation policy between the U.S. and Germany are listed below. These factors have made car use much cheaper, easier, and more convenient in the U.S. than in Germany. The combination of anti-car policies with measures that increased the attractiveness of non-automobile modes at all levels of government has been key to more limited car use in Germany.

(1) All levels of government in the U.S. have made highway funding their first priority at the expense of other modes of transportation, whereas Germany has had a more balanced funding approach across all modes of transportation. In the U.S. for the last four decades, revenues collected from road users by all levels of government have been 30 to 40 percent lower than the costs of road construction and maintenance. Germany also heavily subsidized road construction and maintenance until the 1980s. Since then, revenues collected from road users in Germany have been higher than roadway expenditures made by all levels of government. Since the year 2000, annual revenues from road users have been 250% higher than annual roadway expenditures.

(2) The U.S. has relied on regulation of the automobile manufacturing industry to improve the energy efficiency of its vehicle fleet. These standards were successful in improving energy efficiency in the 1980s. In Germany, historically high gasoline taxes have bolstered demand for fuel efficient cars. Since the 1990s, U.S. fuel efficiency regulations have been only adjusted minimally, while Germany has continued to increase its gasoline tax and to levy higher annual registration fees from more polluting cars with larger engines.

(3) In the U.S., large portions of the revenue generated from road users have been earmarked for highway expenditures. As a result, highway investments have had their own guaranteed funding source and have not had to compete for funds with other government projects. By German law, revenues from road users become part of the general fund and can be used for other expenditures. As such, gas tax increases were for a long time seen as a means of generating additional government revenue. In the late 1990s, Germany for the first time increased its gas tax with the intended purpose of reducing energy use in the transportation sector.

(4) All levels of government in Germany have a long tradition of providing subsidies for public transportation. In Germany and the U.S., transit companies were originally privately owned, but government subsidies started much earlier in Germany. In the U.S., the federal government has only subsidized public transportation since the 1970s, when most of the privately owned transit systems had already gone bankrupt and been disassembled. In 1991, the U.S. federal government renewed its funding priorities for public transportation. This policy shift in the U.S. marked a convergence of public transportation policies at the federal level in both countries.

In 2005, transit subsidies per passenger and passenger kilometer of transit use were lower in Germany than in the U.S. The share of government subsidies in transit operating budgets is almost 50 percent lower in Germany than in the U.S. Policies at the local and regional levels still differ in the two countries. As early as the 1960s, Germany's transit operators began coordinating their fares and timetables region-wide to provide inexpensive, convenient, and seamless public transportation service for their customers. In the U.S., some cooperation between transit operators exists as well, but overall customers still face fragmented timetables and fare structures.

(5) Greater road supply per capita and fewer speed limits in urban areas in the U.S. have resulted in average car travel speeds that are 25 percent higher than in Germany. In urban areas in Germany, car speeds are often reduced through speed limits and area wide traffic calming. For example, cities like Berlin, Muenster, Bonn, and Munich have traffic calmed over 70% of their urban roads.

(6) In Germany, promotion and coordination of walking, cycling and transit use as viable alternatives to the automobile have been combined with local policies limiting car access to cities and car parking. Since the 1970s, many German cities and villages—initially without any federal guidance—have limited car parking in city centers and for new developments. At the same time, many municipalities have created car-free pedestrian zones in city centers and banned the automobile from their downtowns. Since the 1970s, cities and states have also installed bike paths, lanes, and bike parking facilities. Together with improvements in public transportation these policies have made non-automobile transportation more attractive. In the U.S., only a few cities have pedestrian zones and most municipalities still have minimum, rather than maximum parking requirements for new developments. Only a few U.S. cities have made major investments in bicycling infrastructure.

(7) Since the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991, U.S. federal transportation legislation has provided more funds for public transportation, cycling, and walking. At first glance, this legislation seems to indicate a shift of U.S. federal policies towards the more balanced transportation funding

priorities of Germany. However, highways are still heavily subsidized by all levels of government in the U.S. State and local governments do not make full use of this newly gained funding flexibility and still spend the majority of their transportation funds for highway construction, operation, and maintenance. Changes in travel behavior since ISTEA have been minimal: vehicle kilometers of car travel are still growing rapidly and the fuel efficiency of the vehicle fleet has not improved since 1995. Transit use, walking and cycling have increased in absolute numbers, but have not gained any mode share relative to the car in the U.S. For example, the number of transit riders increased by over 23% from 1995 to 2005, but transit mode share remained at 1.6% (APTA, 2006b).

The density, mix of land uses, and compactness of German settlements also help to explain the lower levels of car use in Germany. Differences in spatial development patterns in the two countries have been shaped by dissimilar geographies, spatial and transportation planning systems, property rights, and local finance systems. Spatial planning in Germany is more stringent and more integrated across levels of government. Formal links and channels of communication exist between different levels of government and between land-use planning and specialized planning sectors (such as transportation). Competition for property taxes and a tradition of home rule and local decision making in the U.S. impede region-wide or state wide land-use controls in the U.S. Major differences also lie in the right to develop property. In Germany, development of land outside of settlement areas is prohibited unless specifically permitted by local, regional and state governments. In the U.S., the opposite is true: property owners have the right to develop their land unless the government can show justification why development should not occur.

The multivariate analysis in this dissertation shows that transportation policy, spatial development patterns, socioeconomic, and demographic factors all play a role in explaining travel behavior. Transportation policies accounted for 25 percent of the variability explained in travel behavior, compared to 25 percent for spatial development patterns and 40 percent for socioeconomic and demographic variables.

The impact of transportation policies and spatial development patterns on daily travel distance is greater in the U.S. than in Germany. For example, the difference in daily travel distance between individuals in dense and low density areas is more pronounced in the U.S. than in Germany. The impact of transportation policies and spatial development patterns on mode choice is larger in Germany. Germans living close to transit, in mixed use areas, and in dense areas make a larger share of their trips by modes other than the automobile. In the U.S., all groups of society in all types of settlements use cars for the majority of their trips.

The expected effects of these explanatory factors are found in both countries: higher income households travel more than poorer households; retirees travel less than employed individuals; and households in dense areas closer to transit drive less. However, these explanatory factors *cannot* capture all variability between countries. For most variables, similar people in the two countries do not display similar travel behavior. Some of these differences might be explained by the country-specific context of transportation policies and settlement patterns. For example, the highest income quartile in Germany uses the car less than the lowest income quartile in the U.S. Similarly, Americans in settlements with population densities greater than 5,000 people per km^2

drive their cars for as many or more kilometers per day than Germans living in settlements with population densities of less than 1,000 people per km^2.

International comparisons of travel behavior have traditionally been hampered by problems with the comparability of data or survey methods. Most studies in the past had to rely on country or city averages, which mask wide variability in individual travel behavior. The unique comparability of the German MiD and the U.S. NHTS surveys constitutes an unprecedented opportunity for individual level international comparisons. While some previously assumed relationships were confirmed through this study, other findings call into question conventional wisdom. A study of individual decisions was the only way to capture these differences.

This dissertation proceeds as follows: First, trends over time in travel behavior in both countries are introduced. Second, explanatory factors for differences in travel behavior found in the international comparative literature are introduced. Third, similarities and differences in transportation policies towards the car, public transportation, cycling, and walking are compared and analyzed as are land-use planning systems and policies. Fourth, multivariate analyses based on two uniquely comparable national household travel surveys from 2001 and 2002 analyze differences and similarities in individual travel behavior between the two countries.

2 Transportation Trends in Germany and the U.S.

This chapter presents trends in travel behavior in Germany and the United States over the last 50 years. Development of motorization, modal split, and mode use are analyzed for the countries as a whole and for selected cities and metropolitan areas. If not indicated differently, comparisons for the years 1950 to 1990 are between the U.S. and West Germany. For the period 1990 to 2003 the U.S. is compared to reunified Germany. Differences in the development of travel behavior between East and West Germany are described in a separate section at the end of this chapter.

Major trends in travel behavior and motorization in both the U.S. and Germany are: 1) increasing average trip distance and trip frequency per person per day; 2) increased motor vehicle ownership and use; 3) overall declining shares for trips made by public transportation and walking since 1950; and 4) an overall convergence of travel behavior between the two countries towards a more car dependent transportation system.

Even though trends are similar, some important differences can be observed. For example: Americans make 13 percent more trips and travel 62 percent more kilometers per day than Germans. Moreover, Americans own 41 percent more automobiles per 1000 population and drive their cars for 120 percent more kilometers per year than Germans.

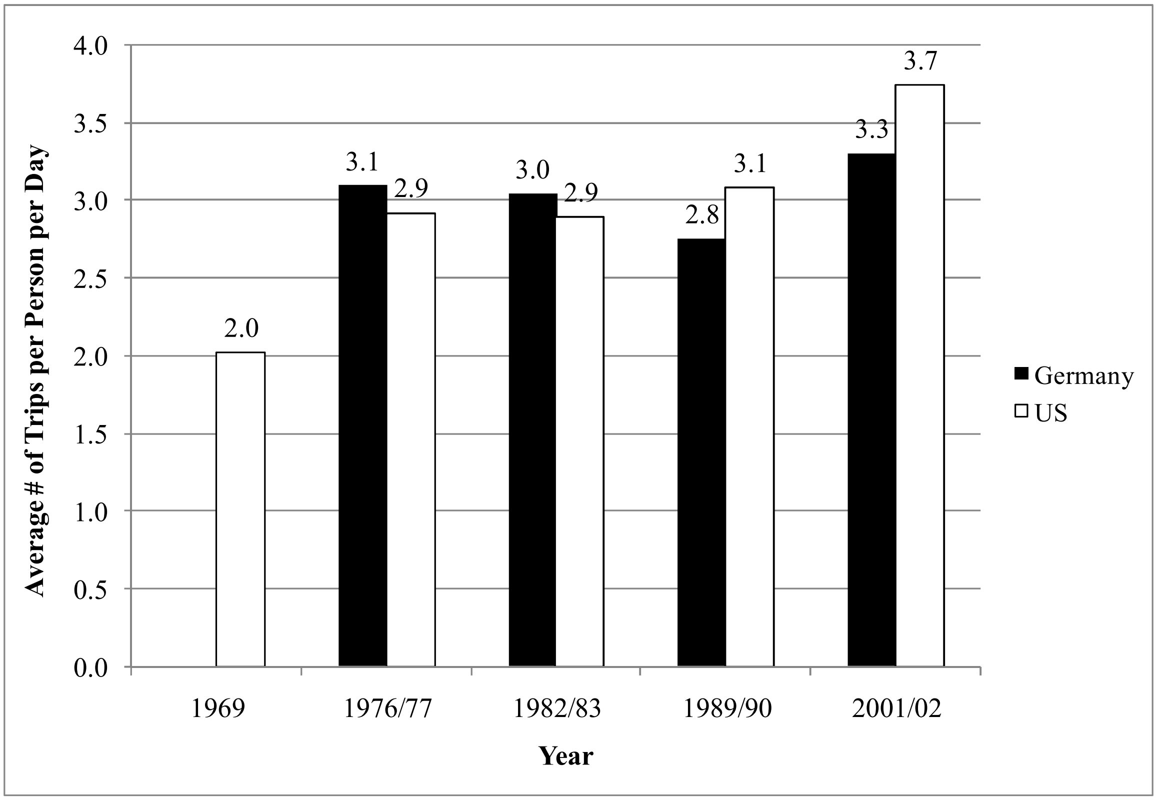
The data presented in this chapter were collected from national statistical offices, the ministries of transportation, the national censuses, and national travel surveys. The 2001 National Household Travel Survey (NHTS) and its predecessors the Nationwide Personal Transportation Surveys (NPTS) have reported on travel behavior for the U.S. since 1969. Similarly for Germany the 2002 "*Mobilitaet in Deutschland*" study (MiD) and its predecessor "*Kontinuierliche Erhebung zum Verkehrsverhalten*" (KONTIV) have described travel behavior in Germany since 1976. For both countries, the surveys have been subject to changes in definitions and methodology over time. Fortunately, subsequent studies have corrected for some of these definitional discrepancies, making the national survey comparable over time. The data reported here are compared over time and between the two countries. Due to changes in survey methods over time, some data had to be adjusted to be comparable with other surveys. The expert reader might therefore not recognize certain statistics. In later chapters the most recent survey data (2001/2002) are used in a multivariate analysis of differences in travel behavior (DIW, 1993, 2004; ORNL, 2004).

2.1 Overview of Trends in Travel Behavior

2.1.1 National Trends in Mobility Levels

According to the NPTS surveys the number of trips made per resident in the U.S. increased from 2.0 trips per person per day in 1969 to 3.7 trips per person per day in 2001, a 85 percent increase (see Exhibit 2.1). In Germany the average number of trips per day increased far less – by only six percent, from 3.1 trips per person per day in 1976 to 3.3 trips per day in 2002 (DIW, 1993; DIW, 2004). On average Americans made 13 percent more trips than Germans in 2001/2002.

Exhibit 2.1 Average Number of Trips per Person per Day in the U.S. and Germany, 1969-2002

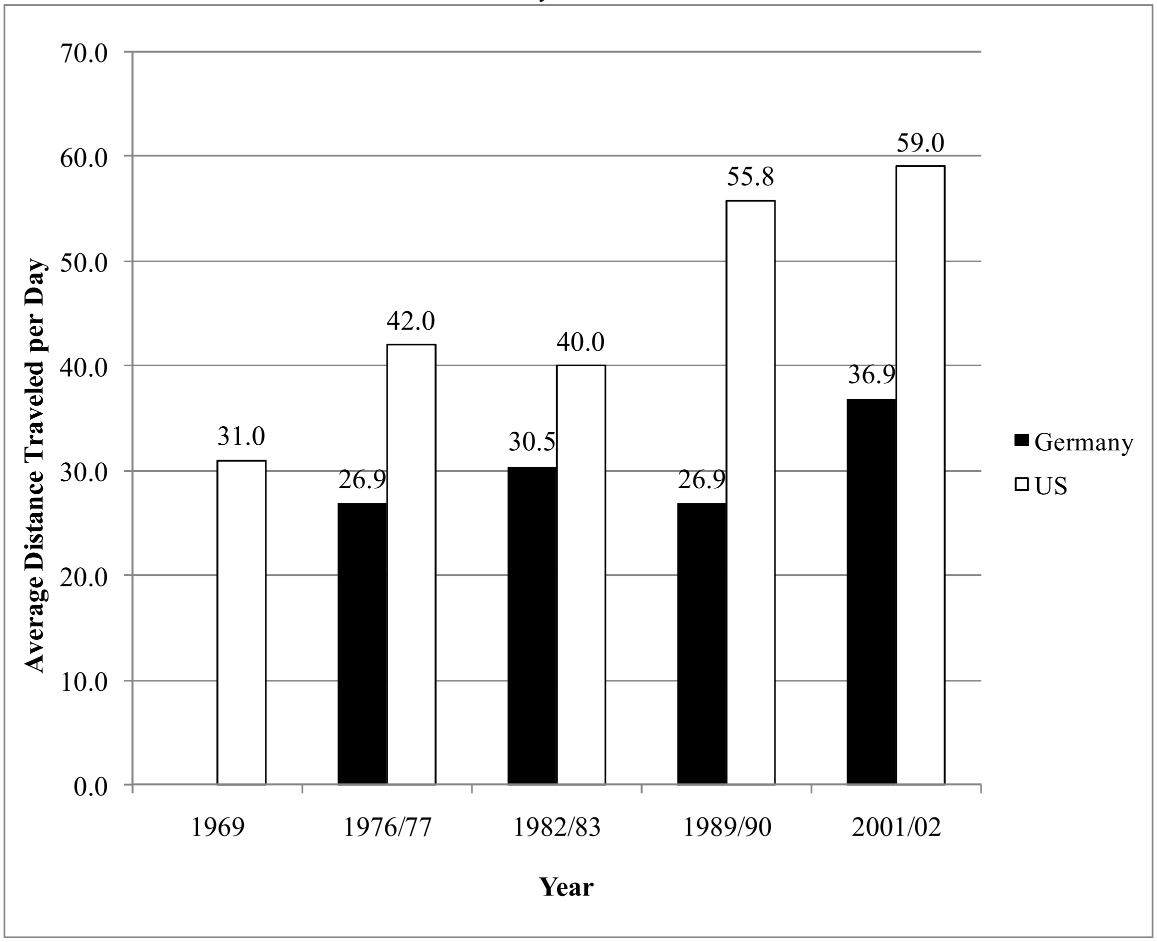


Source: (DIW, 1993, 2004; ORNL, 2004)

Note: *The decrease in number of trips in 1989 in Germany is related to changes in data collection and estimation techniques (DIW, 1993).*

In the U.S. the total distance traveled per resident increased by 90 percent from 31 kilometers per day in 1969 to 59 kilometers per day in 2001 (see Exhibit 2.2). This increase cannot be completely attributed to changes in travel behavior; however, as the methodology for the NPTS changed in 1990/1995, recording tentatively more trips than earlier surveys. Total daily distance traveled per resident in Germany was 27 kilometers in 1976 and 37 kilometers in 2002 (DIW, 1993, 2004; ORNL, 2004). This is a 37 percent increase in distance traveled. In 2001/2002 Americans traveled about 60 percent more kilometers per day than Germans; virtually the same percentage difference as in 1976/1977.

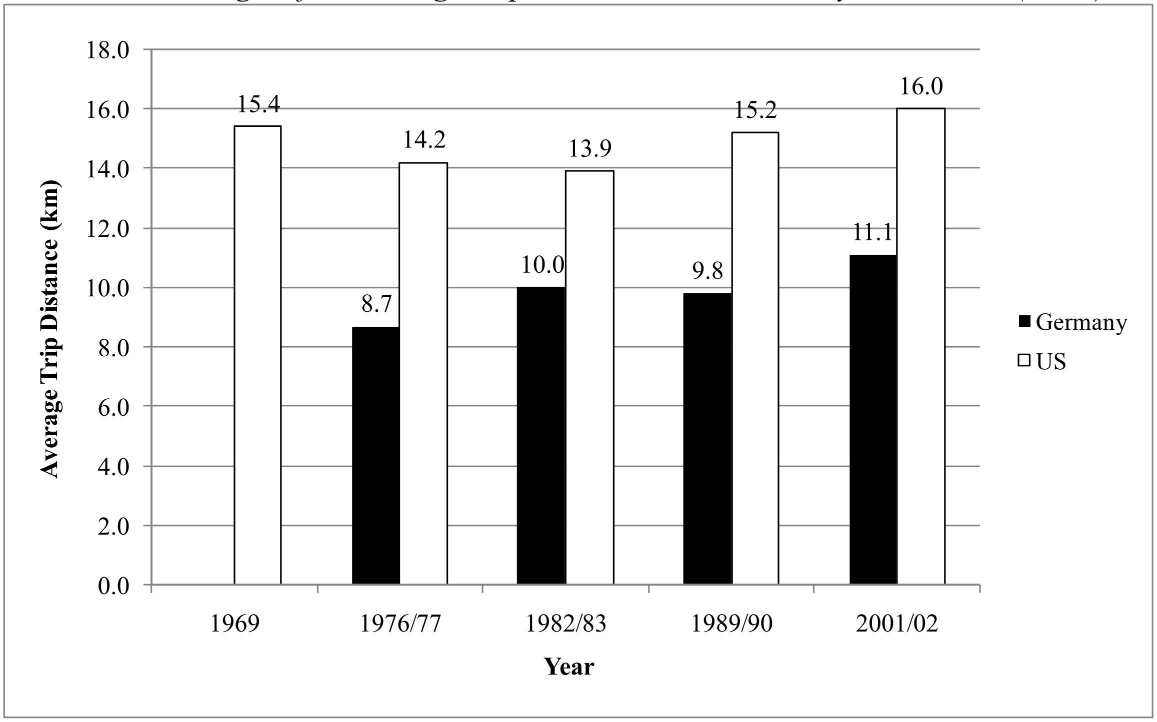
Exhibit 2.2 Average Total Kilometers of Daily Travel per Resident in the U.S. and Germany, 1969-2002



Source: (DIW, 1993, 2004; ORNL, 2004)

The average trip was 44 percent longer in the U.S. than in Germany: 16 kilometers compared to 11 kilometers. In both countries average trip length increased by about two kilometers since 1976/1977 (see Exhibit 2.3). Due to the overall shorter trip distance in Germany that represents a 25 percent increase in Germany, but only a 12 percent increase in the U.S.

Exhibit 2.3 Length of an Average Trip in the U.S. and Germany, 1969-2002 (in km)



Source: (DIW, 1993, 2004; ORNL, 2004)

While trends toward increasing mobility were similar in both countries over the last 30 years, large differences still exist. In 2001/2002, Germans still made fewer and shorter trips than Americans.

2.1.2 National Trends in Motorization and Modal Split

As shown in Exhibit 2.4, automobile and light truck ownership grew steadily in Germany and the U.S. over the last 50 years. In 1950 Germans owned only 12 cars per 1000 population. This number had increased almost fifty fold to 560 cars per 1000 inhabitants in 2005[10] (BMVBS, 1991-2007; Pucher & Lefevre, 1996). The 1950 statistic is depressed by the impacts of WWII and the resulting economic and infrastructure destruction in Germany. In 1939, shortly before WWII, car ownership levels had already

[10] Just considering population at driving age (18 and older for Germany) this number would be 668 cars and light trucks per 1000 population 18 and older in 2005. In the U.S. this would be one car, SUV, or and light truck per inhabitant 16 (median driving age) and older in 2005.

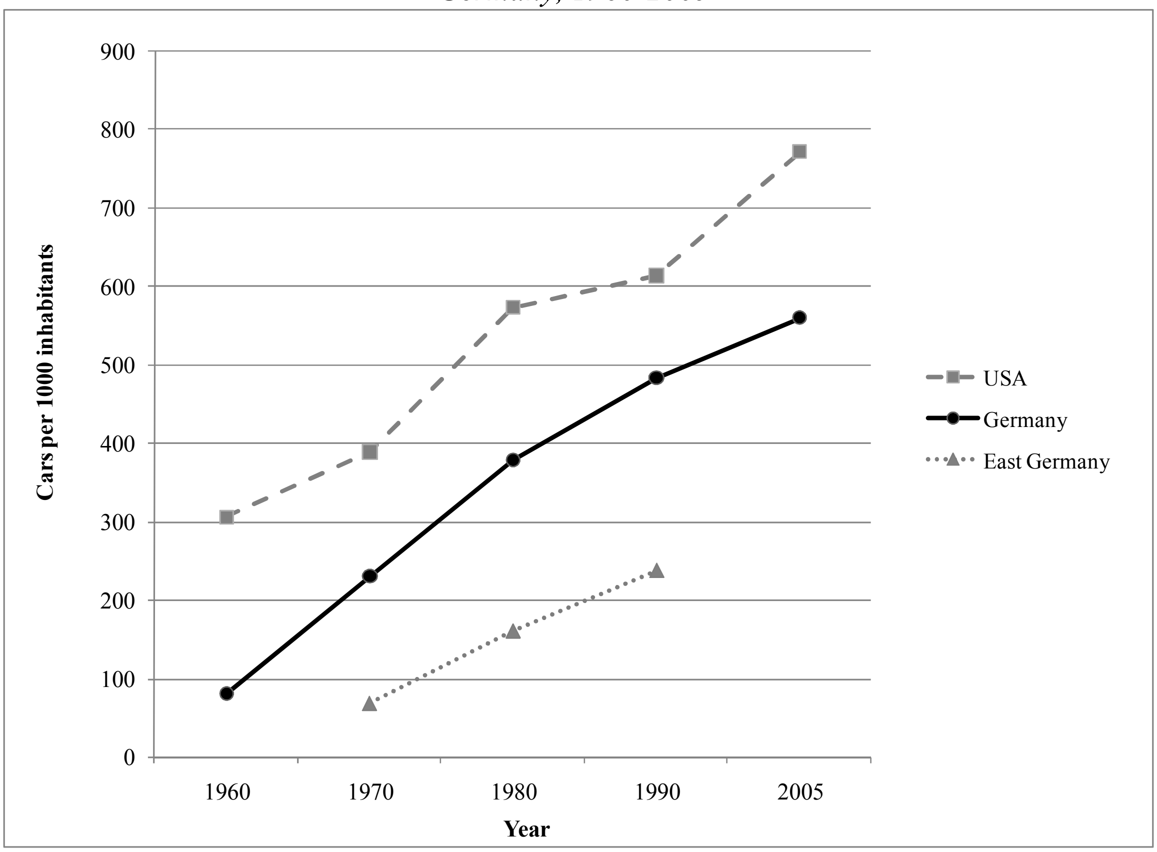
reached 22 cars per 1000 inhabitants (KBA, 2006). Since 1950 car ownership grew constantly and reached 482 in West Germany just before reunification in 1990, which was then the second highest rate in the world after the U.S. (Pucher, 1994). The development of auto-ownership levels in East Germany is described in detail later in this chapter, but motorization rates were much lower than in West Germany, only 224 cars per 1000 in 1988 (BMVBS, 1991-2007). From reunification in 1990 to 2005 auto-ownership levels increased by 13 percent from 458 to 560 for Germany as a whole.

The U.S. always had the highest levels of automobile ownership in the world. Mass auto ownership started much earlier in the United States than in any European country, as early as in the 1920s and 1930s. In 1939 there were already over 200 cars per 1000 inhabitants in the U.S., a rate that was about 10 times higher rate than that of Germany (FHWA, 1990-2008; KBA, 2006).

Exhibit 2.4 shows that from 1960 to 2005 car ownership grew steadily in the U.S. and West Germany. From 1960 to 1990 the percentage gap in car ownership between the two countries was closing: In 1960 Americans owned four times as many automobiles as West Germans. By 1990 Americans only owned 27 percent more vehicles than Germans. Since 1990 this percentage gap increased (for now reunited Germany) to 40 percent in 2005.

From 1990 to 2005 car and light truck ownership in the U.S. grew by 23 percent from 613 to 760 cars per 1000 population. As indicated above, the growth of vehicle ownership in the U.S. from 1990 to 2005 was faster than in reunited Germany as a whole (13 percent), even though East Germany caught up to West German levels and car ownership skyrocketed there. It is noteworthy, that in the U.S. the 1990s showed a decline in automobile ownership[11], but an increase in ownership levels of light trucks, minivans, pickup trucks, and Sport Utility Vehicles (SUVs), indicating growth in sales of larger vehicles (FHWA, 1990-2008).

Exhibit 2.4 Trends in Automobile Ownership per 1000 Population in the U.S. and Germany, 1960-2005



Source:(BMVBS, 1991-2007; FHWA, 1990-2008; Pucher & Lefèvre, 1996)

Although, the gap in motorization levels between Germany and the U.S. narrowed over the last 40 years, in 2005, Americans still owned 40 percent more motor vehicles per capita than Germans.

[11] The Federal Highway Administration defines automobiles as sedans, station wagons, and taxi cabs (details online at: http://www.fhwa.dot.gov/policy/ohpi/hss/guide.htm).

2.1.3 Car Ownership per Household

The increase in vehicle ownership from 1969 to 2002 in both countries led to a decrease of the percentage of households without cars and an increase of the percentage of households with multiple cars (see Table 2.1). In the U.S. in 1969, 21 percent of households had no car (ORNL, 2004). By 2001 this percentage had dropped by more than half to only eight percent of households without a car. In Germany the percentage of households without automobile dropped from 38 percent in 1976 to 19 percent in 2002 (DIW, 1993, 2004). Compared to the U.S. the percentage of households in Germany without an automobile is two to two and a half times higher. Similarly the percentage of households with two or more vehicles is twice as high in the U.S. as in Germany (60 percent vs. 30 percent).

The distribution of household car-ownership levels in Germany in 2002 (20 percent of households without a car, 50 percent with one car, and 30 percent with two cars or more) reflects roughly the percentage distribution for the U.S. in 1969. This underscores the much higher and earlier prevalence of car ownership in the U.S.

Table 2.1 Household Automobile Ownership in the U.S. and Germany, 1969-2002

		1969	***1976/77***	***1982/83***	***1989/90***	***2001/02***
HH without car	U.S.	21%	15%	14%	9%	8%
	Germany		38%	33%	27%	19%
HH with 1 car	U.S.	48%	35%	34%	33%	31%
	Germany		51%	50%	53%	53%
HH with 2 and more cars	U.S.	31%	40%	53%	58%	60%
	Germany		11%	17%	20%	27%

Source:(DIW, 1993, 2004; ORNL, 2004)

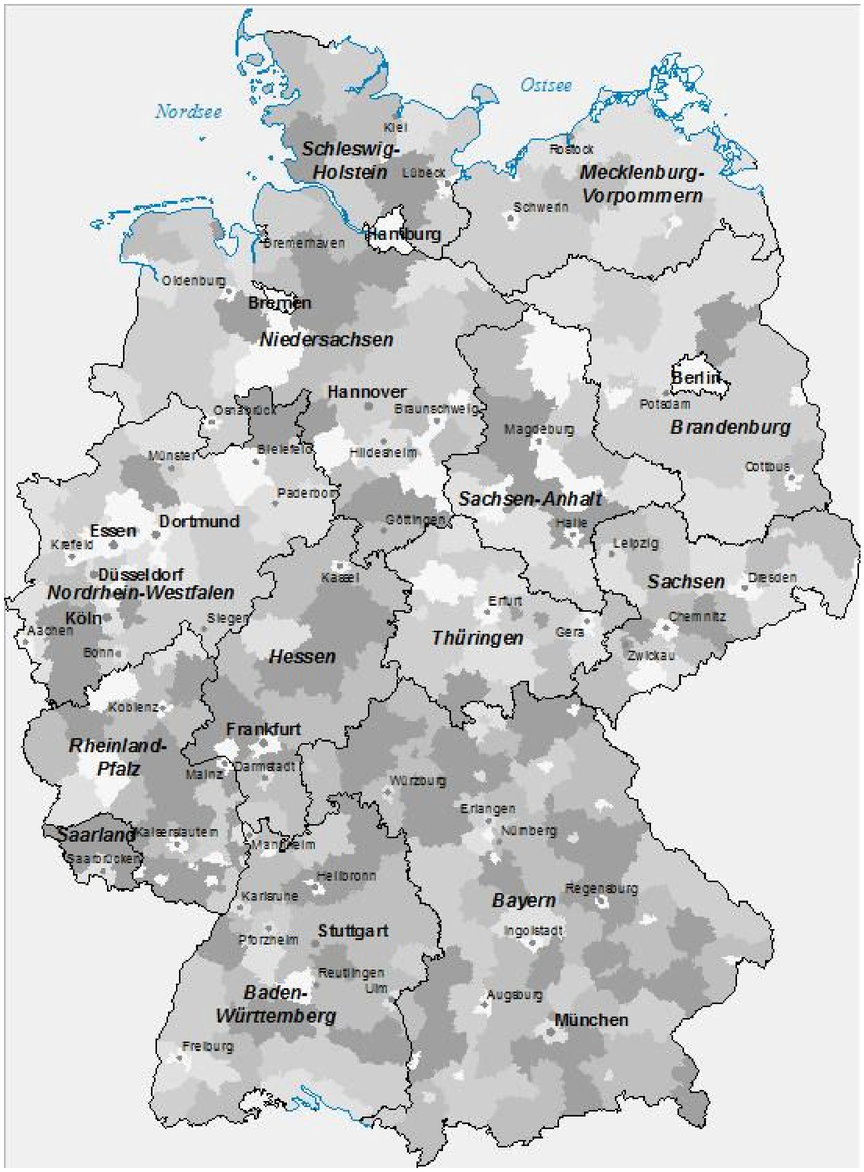
2.1.3.1 <u>Automobile Ownership Levels in Cities</u>

National trends in car ownership hide variability within the country and across cities. According to the Oak Ridge National Laboratories (ORNL), larger metropolitan areas in the U.S. have more households without automobiles than smaller MSAs or areas not in a MSA. The percentage of households without a car outside an MSA dropped from 12 percent in 1977 to six percent in 2001. In U.S. metropolitan areas with more than three million inhabitants the percentage of households without cars fell from 26 percent in 1977 to 12 percent in 2001 (ORNL, 2004).

In Germany 32 percent of households in centers of large agglomerations do not own a vehicle, while only 17 percent of households in low density rural areas do not have an automobile (DIW, 2004). The data are not completely comparable to the data for the U.S. presented above, as definitions for agglomerations and rural areas differ between the countries.

The German Ministry of Spatial Planning (INKAR, 2005) reports on cars per 1000 inhabitants for different cities and agglomerations. Their data show that vehicle ownership in dense cities or agglomeration is lower than in suburban and rural areas. This is indicated by the lighter colors found for most cities in Exhibit 2.5 below.

Exhibit 2.5 Automobile Ownership Density in German Counties, 2002

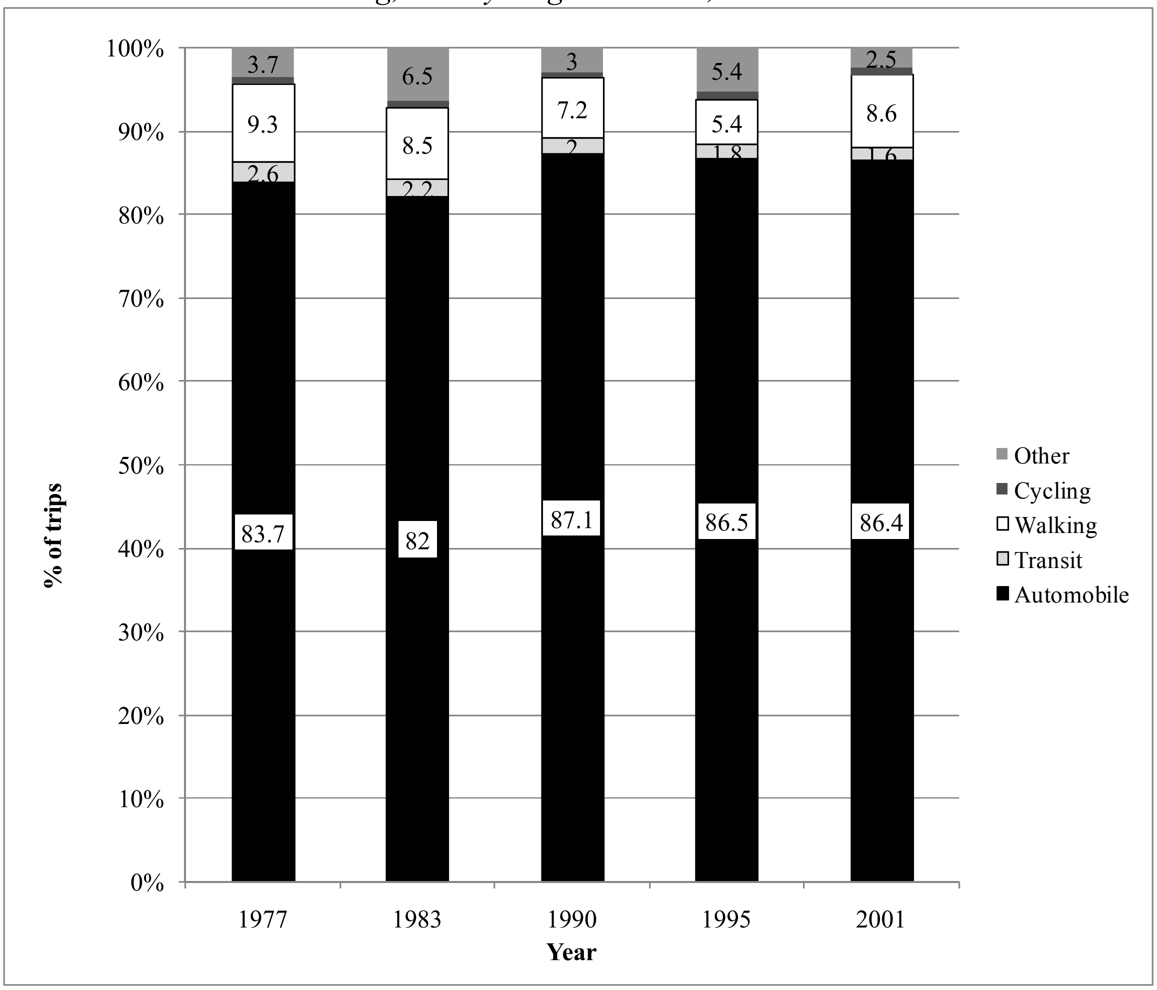


(Legend: light color: low level of car ownership, dark: high level of car ownership; NOTE: generated from INKAR database)

The petroleum company Aral (ARAL, 2004) reports on vehicle and automobile ownership in large German cities. According to their study, in 2004 the number of cars per 1000 population ranged from 365 in Berlin to a high of 748 in Wolfsburg, the headquarters of the car manufacturer Volkswagen. They report a motorization rate of 474 cars per 1000 population for German cities.

2.1.4 National Trends in Modal Split

Exhibit 2.6 Trend of Percentage of All Trips Made by Automobile, Public Transportation, Walking, and Cycling in the U.S., 1977-2001



Source: (ORNL, 2005)

High levels of motorization in the U.S. are one cause for the high percentage of all trips made by automobile. The National Household Travel Survey (NHTS) 2001 and its predecessors the Nationwide Personal Transportation Surveys (NPTS) report on the modal split for all trip purposes for automobile, transit, cycling and walking since 1977.

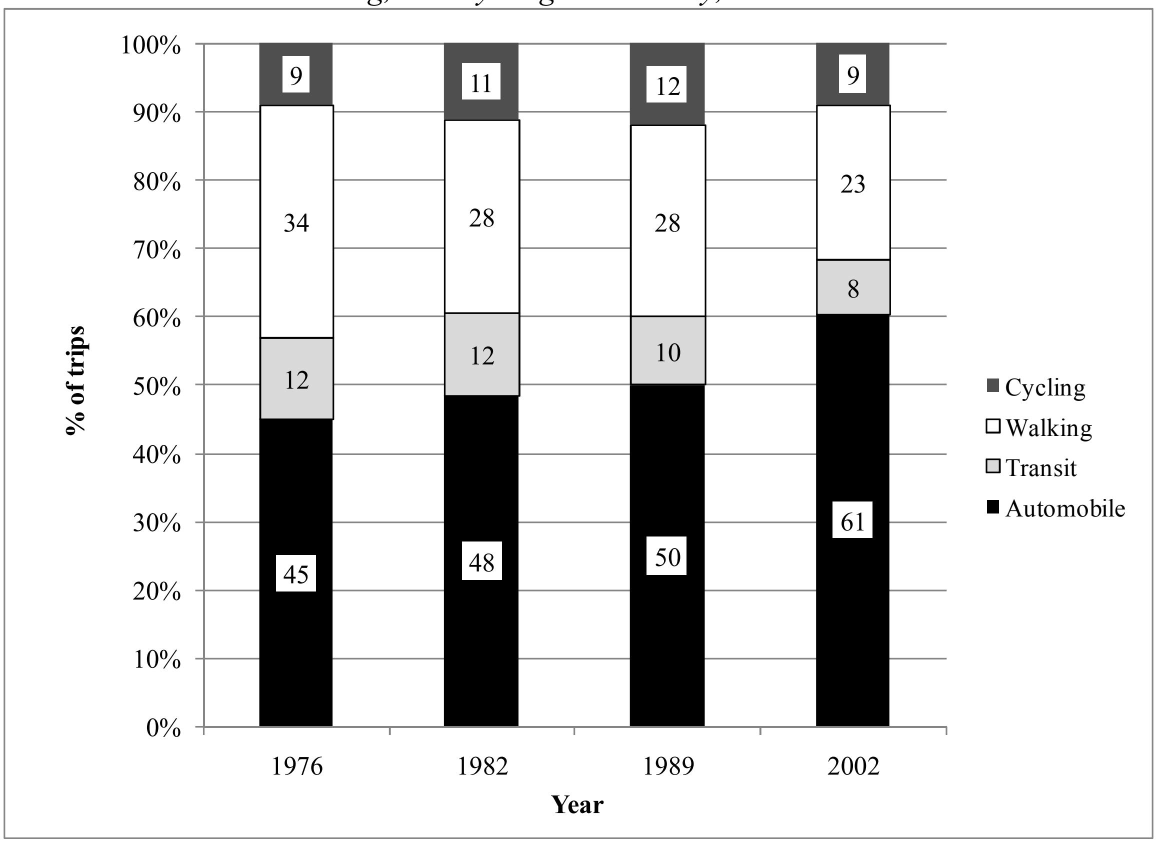
The NPTS was conducted for the first time in 1969, but did not include walking and cycling then and is therefore not necessarily comparable. Since 1969, more than 80 percent of all trips have been made by automobile in the U.S. (see Exhibit 2.6 above). This number grew steadily and reached 86.4 percent in 2001 (ORNL, 2004; Pucher & Renne, 2003). While the modal share of the automobile increased, the share of trips made by foot, bike or public transit decreased. The latest increase in the percentage of walk trips from 1995 to 2001 is most likely completely accounted for by a change in data collection methodology, putting a greater emphasis on collecting data on short walk trips omitted in previous surveys.

The U.S. Census Bureau reports on the modal split for the journey to work and confirms the trend of increased automobile use since 1960. The percentage of U.S. residents driving to work increased from 67 percent in 1960 to 88 percent in 2000. While the modal share of the automobile increased, the share of transit, walking and cycling decreased for work trips. While transit was used for nine percent of work trips in 1969, its share had decreased to only five percent by 2000, a 40 percent decline.

Similar to the trend in the U.S., the data for Germany also display an increase in automobile modal split (see Exhibit 2.7). In contrast to the U.S., however, a larger percentage of trips was still made by walking, cycling and transit in 2002 in Germany. Similar to NHTS and NPTS, the "*Mobility in Germany Survey*" 2002 (MiD) and its predecessors (KONTIV 1976, 1982 and 1989) report on modal splits for all trip purposes. The percentage of trips made by automobile increased from 45 percent in 1976 to 61 percent in 2002, while transit use declined from 12 percent of all trips to eight percent (see Exhibit 2.7).

There is some debate about the low percentage of transit trips in the MiD 2002, which could be a result of a biased sample (Broeg, 2004). Other city and region-wide surveys for Germany estimate the transit share to be well above 10 percent of all trips.

Exhibit 2.7 Trend of Percentage of All Trips Made by Automobile, Public Transportation, Walking, and Cycling in Germany, 1976-2002



Source:(BMVBS, 2004)

Germany's share of non-automobile travel is four times the U.S. share. Its bike share is 10 times higher than the U.S. mode split for bikes, and transit-use accounts for four times more trips than the U.S. share. With 23 percent of all trips, walking has the second highest mode share behind the automobile in Germany, but it accounts for only nine percent of all trips in the U.S. Even though the share of car trips increased more strongly in Germany over the last 30 years, Germans in 2002 used the car for a lower percentage of trips than Americans did in 1969.

2.1.4.1 Trends in Modal Split in Cities and Metropolitan Areas

National Trends in modal split hide variation within countries and across cities. Neither the NHTS/NPTS for the U.S. nor the MiD/ KONTIV contain data for specific cities or metropolitan areas. They only summarize mode splits by city size categories. Unfortunately, definitions of city size categories for the NPTS were changed in the early 1990s, so that data collected after 1990 are not necessarily comparable to data collected earlier (ORNL, 2005) .

FHWA reports U.S. Census Bureau trends on the percentage of workers driving to work in 48 "*major*" metropolitan areas for the time period 1980-2000. Table 2.2 below shows that all metropolitan areas, except New York, display an automobile mode split of at least 80 percent of work trips in 2000 (FHWA, 2003).

The mode split of transit for the work trip fell in most cities from 1980 to 2000. The only notable exception is Las Vegas with a two percentage point increase in transit mode split from 1980 to 2000. In contrast to Germany, there is huge variation in transit modal split across U.S. metropolitan areas. New York's mode split for transit is two to six times larger than all other metropolitan areas with more than one million workers (FHWA, 2003).

The percentage of work trips made on foot has declined from 1980 to 2000 in every metropolitan area presented here. The only metropolitan area with a mode split for walking higher than five percent in 2000 was New York (FHWA, 2003), which is two to five times larger than in other metropolitan areas displayed in Table 2.2. The percentage of work trips made by bike is very small, less than one percent in most metropolitan areas. The cycling mode share in 2000 also shows considerable variability ranging from 1 to 1.4 percent in Sacramento and San Francisco to 0.1 percent in Dallas, St. Louis, Kansas City, San Diego and Tampa.

Table 2.2 Percentage Share of Worktrips by Mode of Transportation in Major U.S. Metropolitan Areas and Percentage Point Change in Mode Split from 1980-2000 (sorted by # of workers in 2000)

		1980			1990			2000			% point change 1980-2000		
	# of Workers in 2000	Car	Transit	Walk	Car	Transit	Walk	Car	Transit	Walk	Car	Transit	Walk
New York	9,319,218	63.9	26.2	7.4	66.2	24.7	6.2	65.7	24.9	5.6	1.8	-1.3	-1.9
Los Angeles	6,767,619	87.3	5.1	3.5	88.9	4.6	3.0	87.6	4.7	2.6	0.3	-0.4	-0.9
Chicago	4,218,108	76.1	16.2	5.7	79.8	13.4	4.1	81.5	11.5	3.1	5.3	-4.7	-2.6
Washington, DC	3,839,052	79.6	12.5	5.1	81.8	11.0	3.9	83.2	9.4	3.0	3.6	-3.1	-2.1
San Francisco	3,432,157	79.3	11.2	4.4	82.8	9.3	3.7	81.0	9.5	3.3	1.7	-1.7	-1.2
Philadelphia	2,815,405	78.4	12.4	6.5	81.6	10.2	5.3	83.6	8.7	3.9	5.2	-3.7	-2.6
Boston	2,898,680	80.2	9.4	7.7	83.2	8.6	5.2	82.7	9.0	4.1	2.5	-0.4	-3.6
Detroit	2,482,457	91.6	3.4	3.3	93.1	2.3	2.4	93.4	1.8	1.8	1.9	-1.6	-1.5
Dallas	2,527,648	91.8	3.4	2.2	92.9	2.3	1.9	92.7	1.8	1.5	0.9	-1.6	-0.7
Houston	2,081,607	91.9	2.9	2.7	91.1	3.8	2.3	91.3	3.3	1.6	-0.6	0.3	-1.1
Atlanta	2,060,632	88.8	7.0	2.0	91.1	4.5	1.5	90.6	3.7	1.3	1.8	-3.4	-0.7
Miami	1,642,866	88.7	4.9	3.2	90.5	4.4	2.3	90.1	3.9	1.8	1.3	-1.0	-1.4
Seattle	1,776,224	82.9	7.5	4.9	86.3	5.8	3.7	84.4	6.8	3.2	1.5	-0.8	-1.8
Phoenix	1,466,434	89.1	1.9	3.4	91.4	2.1	2.7	90.0	2.0	2.1	0.9	0.1	-1.3
Minneapolis	1,595,550	83.0	8.4	5.1	87.7	5.2	3.3	88.4	4.5	2.4	5.4	-3.9	-2.6
Cleveland	1,375,774	86.7	7.6	3.7	90.1	4.4	3.0	91.1	3.4	2.1	4.4	-4.2	-1.6
San Diego	1,299,503	81.2	3.3	9.9	86.0	3.3	4.6	86.9	3.4	3.4	5.8	0.1	-6.5
St. Louis	1,238,964	88.6	5.6	3.3	92.0	2.9	2.2	92.5	2.4	1.6	3.9	-3.2	-1.6
Denver	1,346,025	85.5	5.8	4.7	88.2	4.0	3.4	87.1	4.3	2.4	1.7	-1.5	-2.4
Tampa	1,063,957	90.4	1.7	3.4	93.1	1.5	2.3	92.1	1.4	1.7	1.7	-0.3	-1.7
Pittsburgh	1,057,354	81.1	10.4	6.6	84.9	7.5	5.1	87.1	6.2	3.6	6.0	-4.2	-3.0
Portland	1,105,133	83.8	7.2	4.5	87.3	4.8	3.4	85.2	5.7	3.0	1.4	-1.5	-1.5
Cincinnati	951,709	88.2	5.6	4.0	90.8	3.5	3.0	91.4	2.9	2.3	3.2	-2.6	-1.7
Sacramento	799,989	86.7	3.4	3.6	91.0	2.4	2.7	88.9	2.7	2.2	2.1	-0.7	-1.4
Kansas City	881,258	90.5	3.8	2.8	92.6	2.1	1.9	93.2	1.3	1.4	2.7	-2.5	-1.5
Milwaukee	816,880	84.6	7.1	5.7	88.5	4.9	4.0	90.0	4.0	2.8	5.4	-3.1	-3.0
Orlando	786,243	89.5	1.6	4.7	92.4	1.4	3.4	92.7	1.7	1.3	3.2	0.1	-3.4
Indianapolis	795,755	91.4	3.0	3.1	92.9	1.9	2.3	93.3	1.3	1.7	1.8	-1.7	-1.5
San Antonio	698,685	86.8	4.5	5.4	89.7	3.6	3.6	90.9	2.9	2.4	4.1	-1.6	-3.0
Norfolk	760,401	83.5	4.5	6.6	87.7	2.2	3.7	91.0	1.9	2.7	7.5	-2.6	-4.0
Las Vegas	702,535	89.9	2.0	3.9	91.5	2.1	3.7	89.5	4.1	2.4	-0.4	2.1	-1.5
Columbus	777,922	88.9	4.2	4.3	91.2	2.8	3.3	91.6	2.3	2.4	2.8	-1.9	-1.9
Charlotte	751,629	92.2	2.6	3.1	93.5	1.8	2.1	93.8	1.4	1.2	1.5	-1.2	-1.9
New Orleans	570,423	83.1	10.1	3.9	87.0	7.0	3.1	87.7	5.6	2.7	4.6	-4.5	-1.2
Salt Lake City	642,688	88.2	4.9	3.5	91.0	3.0	2.3	90.3	3.0	1.8	2.1	-1.9	-1.6
Greensboro	618,921	93.2	1.6	2.6	94.0	1.1	2.3	94.3	0.9	1.6	1.1	-0.8	-1.1
Austin	649,645	88.7	2.9	4.1	90.3	3.2	2.9	90.2	2.6	2.1	1.5	-0.3	-2.0
Nashville	621,221	91.1	3.5	2.8	93.1	1.7	1.9	93.5	1.0	1.5	2.4	-2.5	-1.3
Providence	555,540	87.2	4.5	6.3	91.2	2.6	3.9	91.3	2.5	3.3	4.1	-2.0	-3.0
Raleigh	617,475	89.7	2.7	4.3	92.2	1.8	3.0	91.4	1.7	2.3	1.7	-1.0	-2.0
Hartford	573,114	87.7	5.3	4.8	90.6	3.5	3.4	91.5	2.8	2.5	3.8	-2.5	-2.2
(continues next page)													
Buffalo	520,350	85.2	6.6	5.9	88.5	4.7	4.4	91.1	3.5	2.7	5.9	-3.0	-3.2

Buffalo	520,350	85.2	6.6	5.9	88.5	4.7	4.4	91.1	3.5	2.7	5.9	-3.0	-3.2
Memphis	511,111	89.1	4.6	4.3	92.0	2.8	2.9	93.9	1.7	1.3	4.8	-2.9	-3.0
West Palm Beach	475,572	90.7	1.9	3.2	93.0	1.4	2.0	91.6	1.4	1.4	0.8	-0.5	-1.9
Jacksonville	527,718	88.2	4.5	3.8	91.4	2.1	2.6	92.9	1.5	1.7	4.7	-3.0	-2.1
Rochester	516,814	86.0	4.9	6.3	89.6	3.1	4.4	90.9	2.0	3.5	4.9	-2.9	-2.8
Grand Rapids	531,924	91.4	1.5	4.1	93.0	1.0	2.7	93.2	0.8	2.1	1.8	-0.7	-2.0
Oklahoma City	509,262	92.9	1.1	2.8	94.0	0.7	2.1	93.8	0.6	1.7	0.9	-0.5	-1.1
Louisville	492,821	90.6	4.5	2.7	92.4	3.2	2.0	92.9	2.2	1.7	2.3	-2.3	-1.0

Red=Changes that do not follow the general trend.

Source: (FHWA, 2003)

The variability of mode split within the U.S. becomes even larger when one analyzes urbanized areas instead of metropolitan areas. The U.S. census defines urbanized areas more narrowly than metropolitan areas, where the latter can include lower density surroundings of a city. "*An Urbanized Area comprises one or more places ("central place") and the adjacent densely settled surrounding territory ("urban fringe") that together have a minimum of 50,000 persons*" (U.S. Census Bureau, 2006c). According to the U.S. Census (and not shown here) in the year 2000, the urbanized area of Davis, California, had a bike mode split of 15 percent for work trips, compared to other urbanized areas with bike splits of 0.1 percent (U.S. Census Bureau, 2000). Similarly, New York City had a transit mode split of 28 percent compared to 0.1 percent of work trips in most other U.S. urbanized areas (U.S. Census Bureau, 2000). Only 11 out of the 50 largest cities in the U.S. had a combined mode share for transit, walking and cycling of over 20% in 2000 (Thunderhead Alliance, 2007; U.S. Census Bureau, 2000).

Socialdata (Socialdata, 2006), a research company from Munich, provides trend data for the mode split for selected German cities from 1980 to 2001. This data is not comparable to the data presented for the U.S. above, as it is for all trip purposes, and not just for work trips. Comparisons of the data should take into account that the share of transit trips is generally higher for work than for non-work trips and that bike trips are mainly made for recreational and not work related purposes in the U.S. As a result the work trip numbers for the U.S. overestimate the percentage of transit use for all trips and underestimate the share of bike trips.

Unfortunately the German data is not collected at exactly the same time in all cities. Therefore the data presented in Table 2.3 shows modal splits collected during three time periods around either 1980, 1990, and the year 2000.

As Table 2.3 shows, in West German cities in 1980 the mode split of automobile use ranged from 34 to 43 percent, about half of the average U.S. percentage. From 1980 to 2000 most cities displayed increased mode shares for the automobile and transit. The increase in transit is in contrast to the U.S., where transit's mode share decreased in most cities. Overall the German mode split for transit is two to twenty times higher than in U.S. cities (excluding New York). Cycling gained mode share or stayed stable in all West German cities. Walking is the only mode that declined between four and 14 percentage points in all cities.

Overall the variability of bike, transit, and walk mode shares across West German cities is much smaller than the variability within the U.S. Cities like Chicago or New York have a 10 to 24 times higher mode share for transit than many other U.S. cities; a magnitude of difference unheard of in West (and East) Germany.

Table 2.3 Percentage Point Change and Percentage Share of All Trips by Mode of Transportation in Selected West German Cities from 1980 to 2000

	Mode Split All Trips 1980 / 1982				**Mode Split All Trips 1990/1992**				**Mode Split All Trips 1998/2001**				**Percentage Point Change 1980 - 2000**			
	Car	Transit	Walk	Bike	Car	Transit	Walk	Bike	Car	Transit	Walk	Bike	Car	Transit	Walk	Bike
Bonn	n.a.	n.a.	n.a.	n.a.	46	14	27	13	42	16	25	17	n.a.	n.a.	n.a.	n.a.
Bremen	40	14	25	20	39	17	21	22	42	16	20	21	2	2	-5	1
Duesseldorf	40	19	32	8	42	18	30	9	47	21	24	8	7	2	-8	0
Freiburg	n.a.	n.a.	n.a.	n.a.	42	18	21	19	39	21	21	19	n.a.	n.a.	n.a.	n.a.
Hannover	34	19	33	13	39	22	23	16	42	22	23	13	8	4	-11	0
Karlsruhe	43	13	30	13	44	16	23	17	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Kassel	38	14	42	5	47	18	28	6	48	18	28	5	10	4	-14	0
Cologne	40	15	32	11	41	17	30	11	42	19	26	12	2	4	-6	1
Munich	38	22	29	10	36	25	24	15	39	24	23	13	1	2	-6	3
Nuremburg	n.a.	n.a.	n.a.	n.a.	46	20	23	10	46	19	24	10	n.a.	n.a.	n.a.	n.a.

Source: (Socialdata, 2006)

The trend data on the city and metropolitan area level confirm national trends in higher levels of car modal split in both countries, with still considerably lower automobile modal splits for West Germany. The difference in automobile modal splits between urban areas is more pronounced than for the countries as a whole. Most German cities have automobile modal splits between 40 and 50 percent, while most U.S. metropolitan areas display car modal splits of over 80 percent. The difference is astounding indeed: Even the city with the highest car mode split in West Germany (Wiesbaden: 53 percent) is below the U.S. metropolitan area with the lowest car mode share (New York: 65.7 percent).[12] Additionally, German cities display much higher mode shares of transit use, walking, and cycling.

This is confirmed by Exhibit 2.8 below. It compares the average mode split for U.S. urbanized areas and German cities by population size categories for the year 2000.[13] In all categories the U.S. car mode split is at least twice as high as in Germany. The transit share is between four and ten times higher in Germany. The mode splits for cycling and walking are about ten times higher in Germany compared to the U.S.

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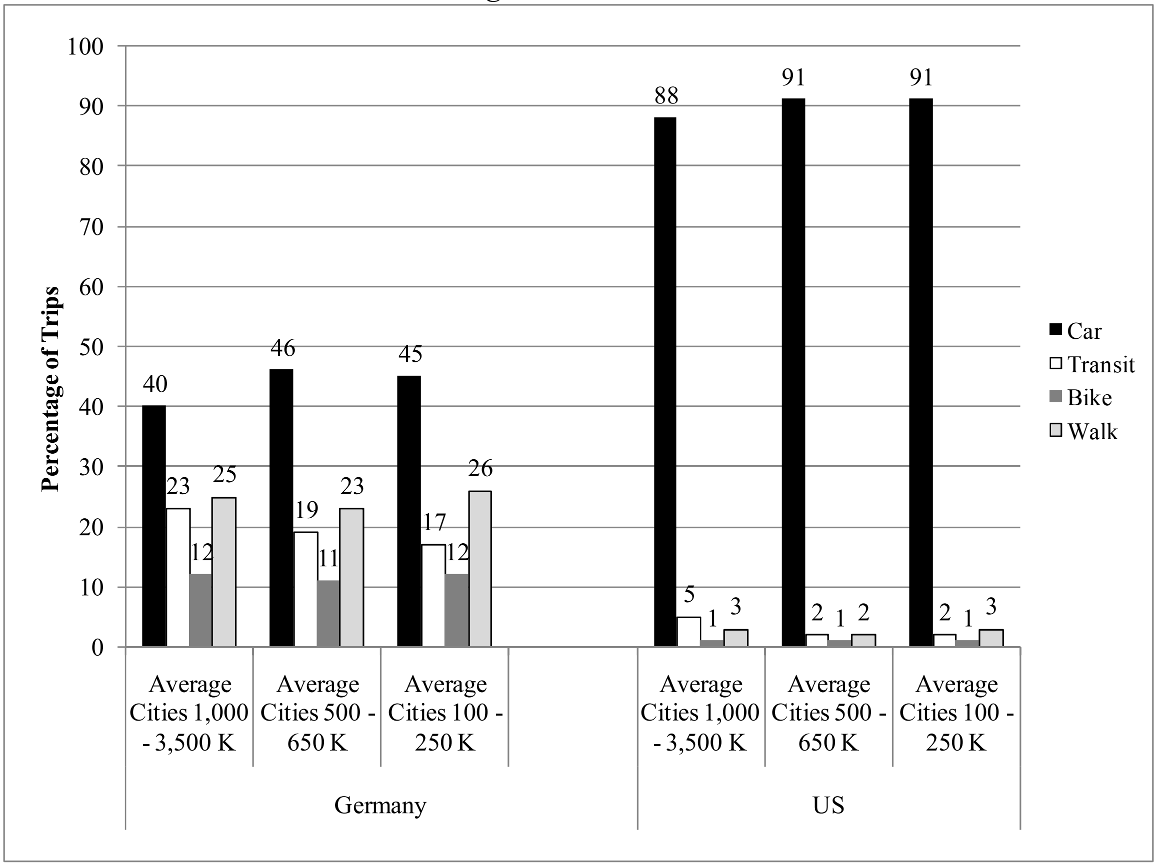
[12] Comparing German cities to U.S. Census urban areas and census places shows a similar picture with the highest German share for car use similar to the lowest U.S. city. The only exception is New York City in the census place data with a modal split of 33 percent of car use.
[13] Recent data for German cities was only available for the city size categories displayed.

Exhibit 2.8 Average Modal Split in U.S. and German Cities, for Different Population Size Categories, 2000-2003



Source:(Socialdata, 2006; U.S. Census Bureau, 2000)

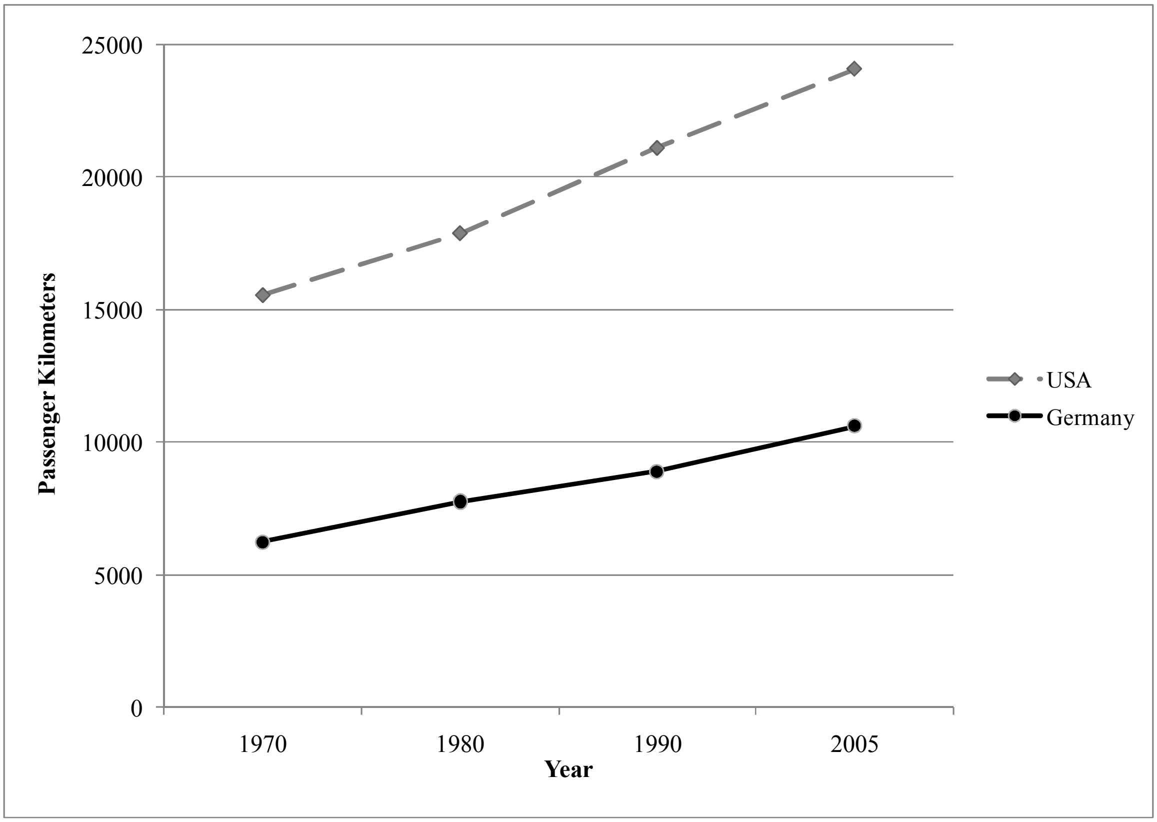
Note: U.S. data are for work trips

2.1.5 National Trends in Car Use

From 1970 to 2005, passenger kilometers of car use have increased by more than 50 percent in both countries. In 2005 Americans drove on average about 24,000 kilometers a year, compared to only 11,000 for Germans (including both West and East Germany). Since 1970, Americans have consistently driven approximately 10,000 kilometers more annually than Germans.[14]

[14] Germans here refers to West Germans until 1990 and the reunified Germany after 1990.

Exhibit 2.9 Trend of Passenger Kilometers of Car and Light Truck Travel per Inhabitant in the U.S. and Germany, 1970-2005

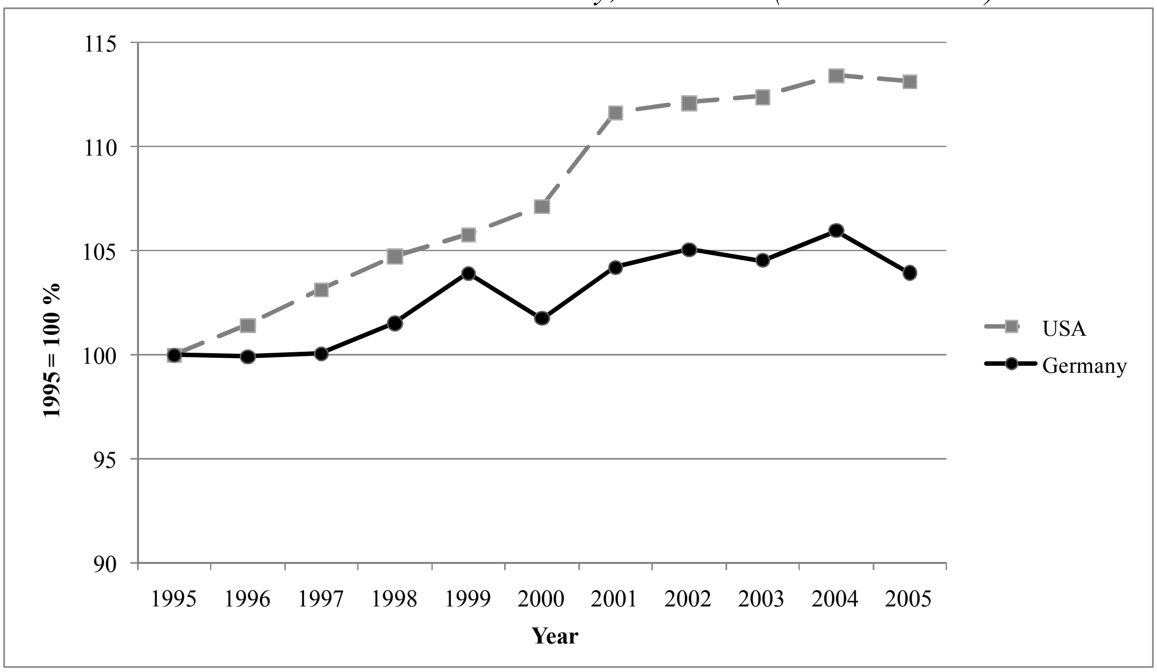


Source: (BMVBS, 1991-2007; FHWA, 1990-2008)

Similar to the increase in light truck ownership described above, kilometers traveled by light truck increased dramatically during the 1990s in the U.S., while automobile travel only grew modestly. Kilometers driven by automobile on urban roads increased by about 12 percent from 1995 to 2004, but kilometers driven by light truck nearly doubled from 1995 to 2004. In 1995, light trucks accounted for 29 percent of all car and light truck kilometers driven on urban roads. This percentage increased to 36 percent in 2004, indicating a precipitous increase in kilometers driven by light trucks (FHWA, 1990-2008).

Undoubtedly, both countries displayed large increases in car use over the last three decades. While car use in the U.S. is currently still growing fast, the growth of passenger kilometers of car use in Germany seems to have slowed down over the last 10 years. From 1995 to 2005 passenger kilometers per inhabitant grew only by about four to six percent in Germany, but by 12 percent in the U.S.

Exhibit 2.10 Growth of Passenger Kilometers of Car and Light Truck Travel per Inhabitant in the U.S. and Germany, 1995-2005 (relative to 1995)



Source: (BMVBS, 1991-2007; FHWA, 1990-2008)

2.1.6 National Trends in Public Transportation Use

Both countries display a nationwide decrease (according to the national travel surveys) of mode share of transit use. Table 2.4, however, shows that the number of total trips made by transit increased from 1970 to 2005. The decline in transit´s mode share indicates an even faster growth in automobile trips.

Table 2.4 displays linked transit trips for German transit authorities and unlinked transit trips for the U.S. The difference between linked and unlinked trips is not trivial. One linked trip can consist of several unlinked trips. While U.S. statistics count every change of transit vehicle on a journey from an origin to a destination separately, German data only report one trip for each movement from an origin to a destination within a transit authority, no matter how many times the passenger switched trains or busses.[15] Therefore U.S. numbers overstate transit ridership by counting the same passenger several times; German numbers on the other hand, understate the number of single transit trips made. Even though the numbers are not completely comparable, trends in transit ridership can nonetheless be identified.

In the U.S., 9.8 billion unlinked transit trips were made in 2005—a 30 percent increase over 7.3 billion transit trips in 1970.[16] The number of transit trips in Germany increased from seven billion in 1970 in West Germany to 10.9 billion in reunified Germany in 2005. The 1970 and 2005 numbers are not necessarily comparable since Germany was reunited and gained 16 million inhabitants in 1990. A look at the average number of transit trips per inhabitant can control for population changes in Germany. The number of transit trips per inhabitant in Germany is about stable since 1970 with between 113 and 125 transit trips per inhabitant per year, with an upward trend over the last 10 years. Every U.S. resident made on average 33 transit trips in 2005; this is slightly down from 36 transit trips per resident in 1970.

On average Germans made four times more transit trips per year than Americans (about 133 vs. 33). The difference is even more stunning, considering the fact that the U.S. data report unlinked trips, resulting in overestimation of ridership, and the German data are linked trips, which results in underestimation of number of trips.[17]

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[15] The German data however reports unlinked trips when passengers change between transit authorities.
[16] In 1970 transit ridership was counted in terms of total trips, a measure similar to unlinked trips, but not completely identical. Unlinked trip data for 1970 does not exist.
[17] One way to adjust linked and unlinked trips is to multiply unlinked trips by the factor 0.7 (Neff, 2006; Polzin & Chu, 2003)). This would result in 22 linked trips per person in the U.S., five times less than in Germany.

Total distance traveled on transit per year is a more comparable statistic and it shows that Germans travel on average four times more kilometers on transit a year than Americans (1,145 kilometers (715 miles) compared to 269 kilometers (168 miles) in 2005). Both countries witnessed an increase in transit miles traveled per resident over the last ten years, due to increasing trip distances in growing metropolitan areas.

Table 2.4 Trends in Public Transportation Passenger Trips and Passenger Kilometers of Travel in the U.S. and Germany, 1970-2005

	1970	1980	1990	1995	2000	2005
Total Unlinked Transit Trips per Year USA (million)*	7332	8567	8799	7763	9363	9815
Population (million)	203.3	226.5	248.8	266.3	281.4	295
*Unlinked Transit Trips per Inhabitant per Year (US)**	*36*	*38*	*35*	*29*	*33*	*33*
Total Transit Trips per Year Germany (million)**	7015	7652	9156	9265	9638	10972
Population (million)	60.6	61.6	80.3	81.8	82.3	82.5
*Linked Transit Trips per Inhabitant per Year (Germany)***	*116*	*124*	*114*	*113*	*117*	*133*
Total Transit Passenger Kilometer US (million)***	n.a.	63766	65829	63693	76266	79485
Transit Passenger Kilometers per Inhabitant (US)	n.a	282	265	239	271	269
Total Transit Passenger Kilometers Germany (million)	60700	65500	77300	86700	90900	94463
Transit Passenger Kilometers per Inhabitant (Germany)	1002	1063	963	1060	1104	1145

* total transit trips per year for 1970 are "total" trips, which are defined very similarly to unlinked trips.
**Contains some unlinked trips, as some passegners on local heavy rail were counted double when switiching to other modes (unlinked trips). Value for 2005 also includes data for small transit providers (fleets of fewer than 6 vehicles).
*** Passenger miles for 1980 do not include demand response.

Source: (APTA, 2006b; BMVBS, 1991-2007)

2.2 Transportation Trends in East and West Germany

While the purpose of this dissertation is to compare current travel in the U.S. and Germany, it is necessary to provide evidence that this comparison is valid given the unique history of Germany in the 20th century. Transportation in East and West Germany is remarkably similar today, given their very different development paths taken before 1991. The following section will describe converging trends since reunification in 1991. Key comparative statistics are presented in Table 2.5.

Table 2.5 Trends of Selected Transportation and Population Indicators for East and West Germany, 1950 - 2003

Population (million)	Germany	66.1	73.2	77.7	78.3	79.8				
	West Germany	47.6	55.9	60.6	61.6	63.7	80.3	81.8	82.3	82.5
	East Germany	18.5	17.3	17.1	16.7	16.1				
Passenger Cars (million)	Germany	0.7	n.a.	15.1	25.9	35.5				
	West Germany	0.6	4.5	14.0	23.2	30.7	36.8	40.3	42.8	44.7
	East Germany	0.1	n.a.	1.2	2.7	4.8				
Cars per 1000 Population	Germany	11	n.a.	194	331	445				
	West Germany	12	80	230	376	482	458	493	520	541
	East Germany	n.a.	n.a.	68	160	237				
Length of "non-local" Road Newtork (in 1000 km)	Germany	176	181	210	220	221	226	229	231	231
	West Germany	129	135	162	172	174	174	174	174	175
	East Germany	47	46	48	48	47	52	55	57	57
Modal Split of Urban Trips (Automobile)*	West Germany	n.a.	n.a.	31	42	46	48	51	n.a.	52
	East Germany	n.a.	n.a.	11	19	25	44	50	n.a.	54
Modal Split of Urban Trips (Public Transport)*	West Germany			17	17	15	16	15		16
	East Germany			23	24	24	15	13		12
Length of Local Raod Network (in 1000km)	West Germany	220	227	270	310	327	410	n.a.	n.a.	n.a.
Passenger km of Car Use (billion km)	West Germany			380	478	602	713.5	836	855.1	872.3
*data for 1972, 1982, 1987,1992,2002										

Source: (BMVBS, 1991-2007; Broeg & Erl, 2003; Heidemann, Kunert, & Zumkeller, 1993)

2.2.1 Transportation since Reunification

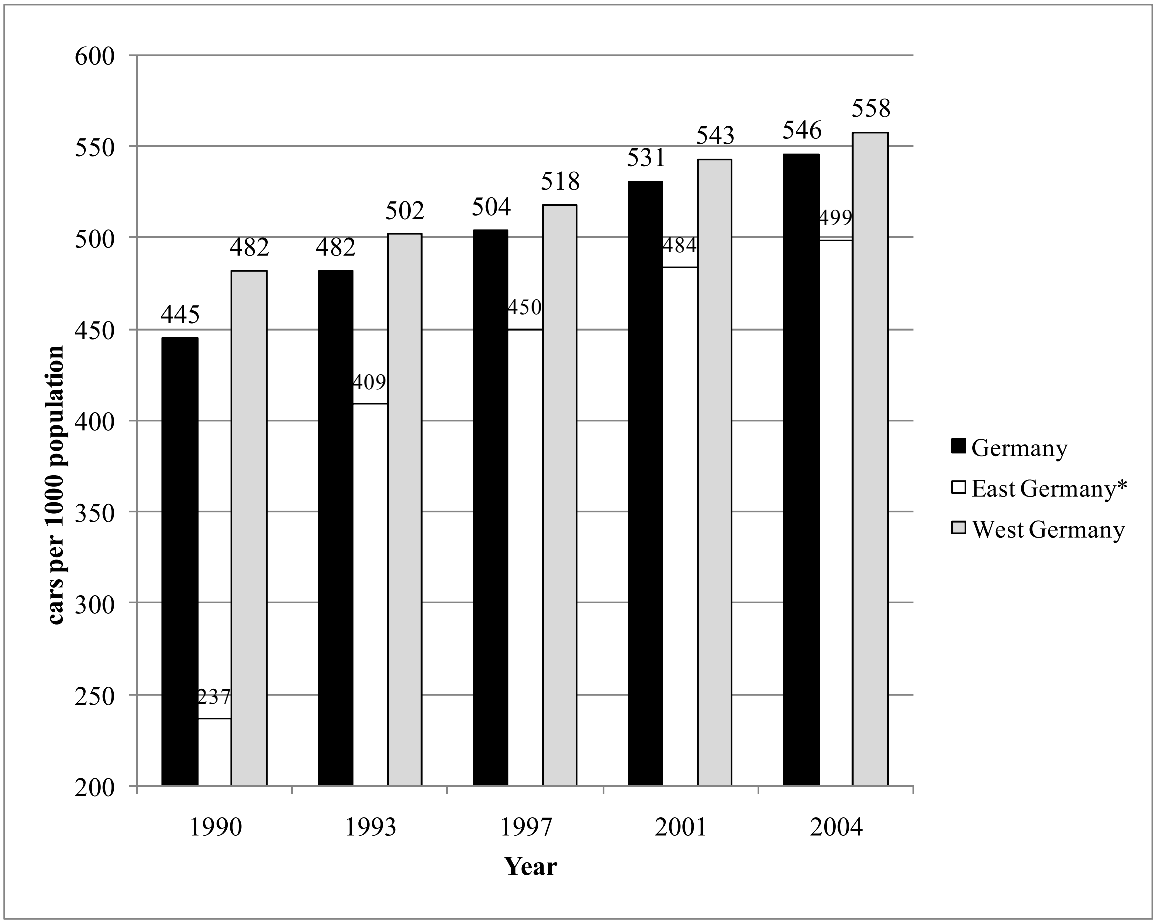
Transportation in East and West Germany after 1990 developed at different paces as a result of their very different transportation systems up to that point. In the following pages, I will introduced trends in automobile ownership and use and modal splits for East and West Germany and for Germany as a whole.

2.2.1.1 <u>Motorization and Modal Split Trends in East and West</u>

Although East Germany in 1989 had the highest motorization rate of all of Eastern Europe, it was low compared to West Germany, which had the second highest car ownership rate in the world (Pucher, 1994). Citizens of the GDR did not have easy access to Western cars and had to order automobiles through the central government. Orders were subject to long delays, often up to 15 years, before obtaining the automobile (Pucher, 1994).

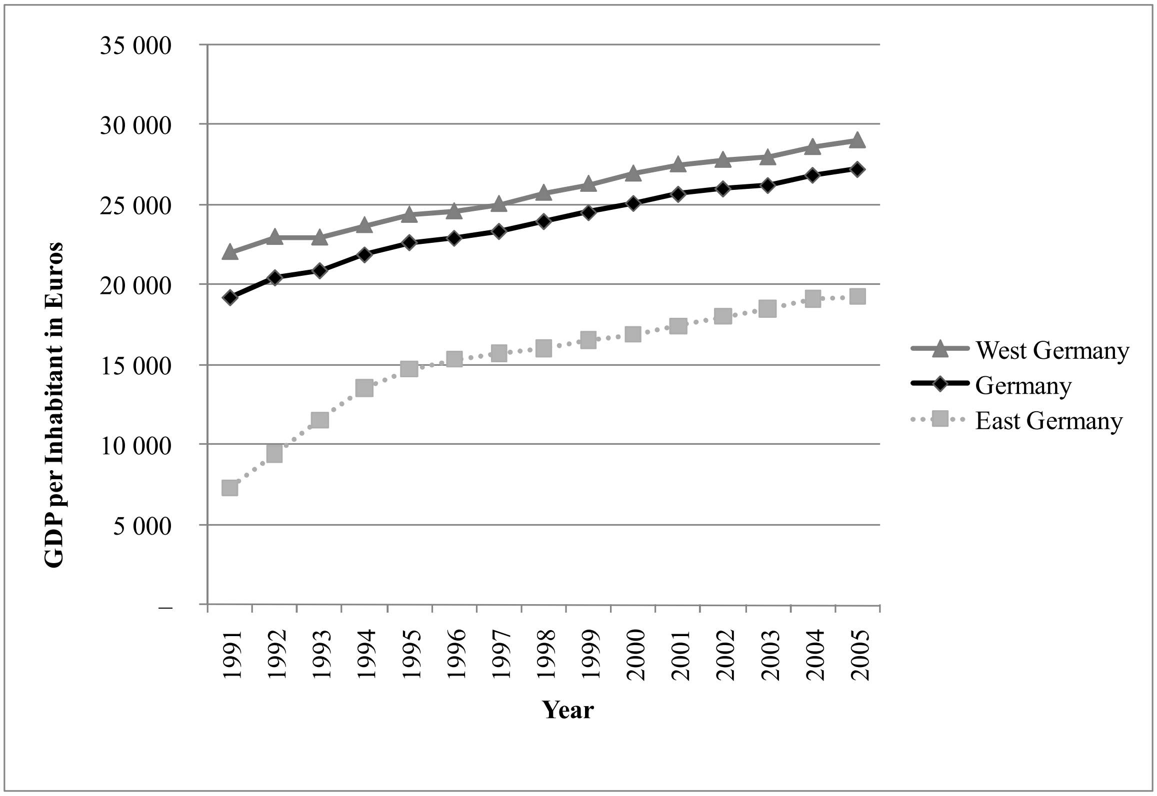
The fall of the Berlin Wall allowed access to Western cars and resulted in a skyrocketing motorization rate in Eastern Germany (see Exhibit 2.11 below). From 1990 to 1993, car ownership in East Germany jumped by 72 percent and had more than doubled by 2004 (BMVBS, 1991-2007). Over the same period, car ownership in West Germany grew by 15 percent. With 499 cars per 1000 inhabitants, East Germany still slightly trails West Germany with 558 cars per 1000 inhabitants (BMVBS, 1991-2007). As theory and many studies suggest, car ownership and GDP growth went hand in hand (Ingram & Liu, 1999; Schafer & Victor, 2000).

Exhibit 2.11 Trend of Automobiles per 1000 Population in East and West Germany, 1990-2004



Source:(BMVBS, 1991-2007)

Exhibit 2.12 Gross Domestic Product per Inhabitant in East and West Germany, 1991-2005 (at current prices in €)



Source:(Volkswirtschaftliche Gesamtrechnung der Laender, 2006)

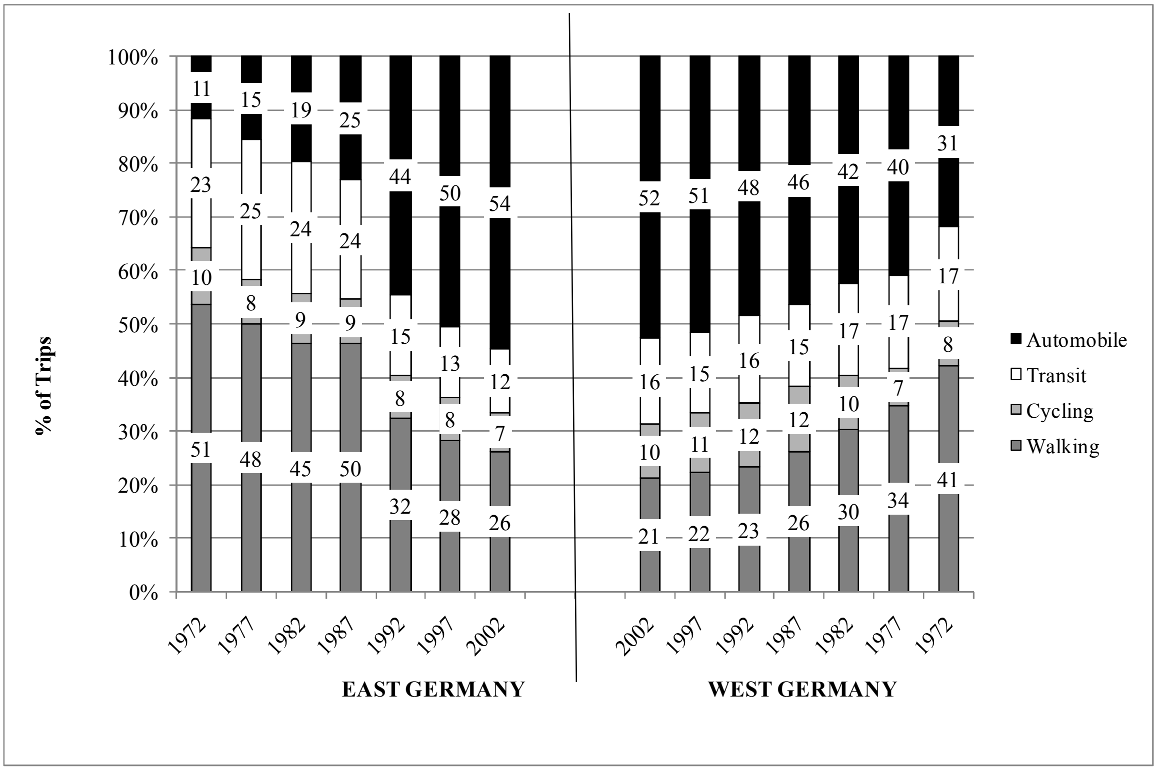
The fall of communism, access to West German currency, and the reconstruction help from West Germany led to fast growing incomes and gross domestic product (GDP) in the East. Exhibit 2.12 above shows that GDP per inhabitant almost tripled in Eastern Germany from 1991 to 2005 from 7,300 Euros (U.S. $ 9,500) to 19,300 Euros (U.S. $ 25,000). The fastest growth was in the first years after reunification, when East German GDP per inhabitant nearly doubled between 1991 and 1995. Part of this increase was spurred by the exchange of the weak East German currency in favor of the strong West German Mark shortly before reunification in the spring/summer of 1990.

West German GDP also grew by about one third during the years 1991 to 2005 from 22,000 to 29,000 Euros (U.S. $ 28,600 to 37,700). The GDP for Germany as a whole also increased by one third from 19,200 to 27,000 Euros (U.S. $ 25,900 to 35,400) (Volkswirtschaftliche Gesamtrechnung der Laender, 2006).[18] Since 1995 the rate of growth in GDP is about the same in West and East Germany.

With increasing income and car ownership in East Germany automobile use grew as well. Exhibit 2.13 below shows that while only 25 percent of all trips were made by car in East German cities in 1987, this percentage had more than doubled by 2002 (Broeg & Erl, 2003). During the same time period, the percentage of urban trips made by foot and public transportation were cut in half, from 50 to 26 percent for walking and from 24 to 12 percent for transit. In West German cities the development was less turbulent. The modal split for automobiles and transit increased slightly while walking and cycling lost about two percent of their mode share. Exhibit 2.13 shows that in only 12 years the modal split in East and West Germany has become almost identical, therefore eradicating striking differences created during 40 years of very different policy environments prior to reunification. The same convergence of travel behavior can be found in other mobility indicators, such as average trip distance (11 km in West and 12 km East Germany in 2002), average automobile occupancy rate (1.3 passengers in East and West in 2002) and average number of trips made per person per day (3.2 in East and 3.3 in West Germany in 2002) (BMVBS, 2004; Broeg & Erl, 2003).

[18] The development of GDP for Germany is similar to West Germany as about 80 percent of all inhabitants live there.

Exhibit 2.13 Convergence of Percentage of Automobile, Public Transportation, Walking, and Cycling Shares of All Trips in East and West German Cities, 1976-2002



Source:(Broeg & Erl, 2003)

The German City Mobility Survey (Staedtepegel, 2003) reports modal splits for selected East and West German cities. Table 2.6 below shows that in 2003 no significant difference in mode split between West and East German cities in comparable city size categories, could be found. Average transit and walk mode shares are almost identical in East and West Germany, with large variability within each part of the country. On average East German cities show an even higher mode split for car use (45 percent vs. 41 percent) and a lower share of bike trips (11 percent vs. 15 percent) than West German cities (Staedtepegel, 2003). Again there is considerably more variability within the two parts of the country than between them. This is remarkable as economic theory would suggest that the big difference in income would lead to divergent travel patterns.

Table 2.6 Percentage Mode Share of All Trips for Selected East and West German Cities, 2003 (by City Size)

	Inhabitants (in 1,000)	% of trips			
West German Cities		Transit	Car	Bike	Walk
Frankfurt	647	22.6	38.5	9.5	29.5
Augsburg	260	18.4	40.5	16.7	24.4
Goettingen	122	12.6	39.8	24.5	23.1
Fuerth	112	18.1	48.4	9.7	23.9
Average West	*285.3*	*17.9*	*41.8*	*15.1*	*25.2*
East German Cities					
Leipzig	498	16.7	44.2	12.6	26.4
Dresden	487	20.3	43	12.3	24.4
Chemnitz	248	14.2	50.2	5.6	30
Magdeburg	226	15.1	53.8	13.7	17.5
Halle	238	18.7	44.5	9.2	27.6
Erfurt	202	20.9	44.3	9.3	25.5
Potsdam	145	19.6	37.4	19.7	23.3
Gera	105	20.2	47.2	4.7	27.8
Jena	102	18.2	38	10.4	33.4
Cottbus	106	11.7	40.5	22.4	25.4
Zwickau	99	10.6	56.3	6.6	26.5
Schwerin	97	18.4	39.6	9.8	32.1
Average East	*212.8*	*17.1*	*44.9*	*11.4*	*26.7*

Source: (Staedtepegel, 2003; Staedtetag, 2006)

Data for Germany as a whole, and not just for cities in West and East Germany, reveal similar numbers. The latest national travel survey (MiD 2002) shows automobile use at 61 percent of all trips, transit at eight percent, walking at 23 percent, and cycling at nine percent of all trips (BMVBS, 2004).

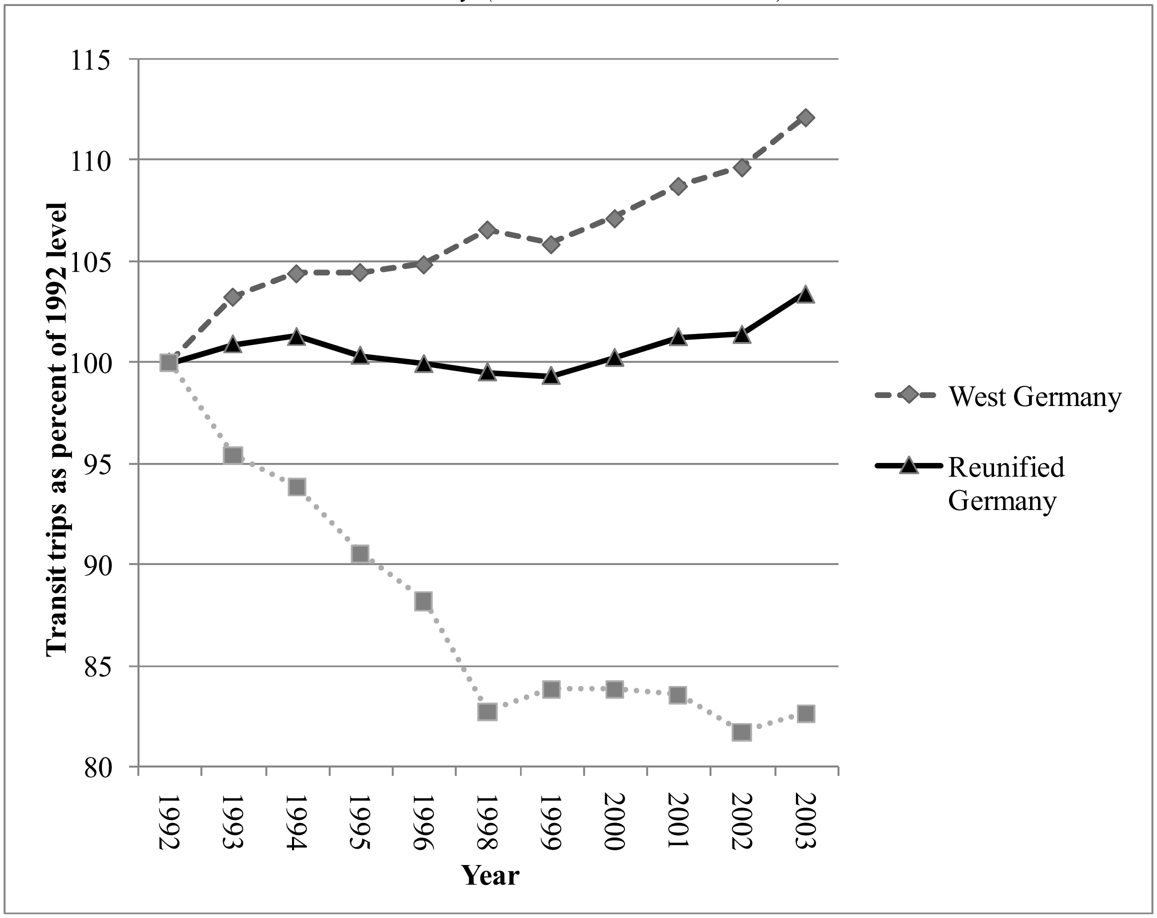
2.2.1.2 Passenger Miles of Car Use

Although car use has increased considerably in East Germany since 1990, the growth in passenger miles traveled by automobile for the whole country seems to have grown at a slower rate or to have even stagnated over the last five years. While annual kilometers driven per resident grew from 6,300 to 11,000 kilometers (3,900 to 6,600 miles) from 1970 to 1999, it hovered slightly above or below 11,000 kilometers from 1999 to 2003 (BMVBS, 1991-2007).

2.2.1.3 Transit Ridership

Similar to transit's slight increase in mode share in cities, the number of transit trips for Germany has increased by four percent from 1992 to 2003 (see Exhibit 2.14). Over the same period, East Germany saw a steep decline in transit ridership of nearly 20 percent. With the fall of socialism, transit subsidies were cut and the relative cost of automobile travel fell (Pucher, 1994). In West Germany the trend was opposite. The number of transit trips increased by 13 percent. For certain regional transit authorities (Verkehrsverbuende) in West Germany, the number of transit passenger trips increased by over 30 percent from 1990 to 2002 (e.g. the Stuttgart, Berlin and Rhein Ruhr regions) (BMVBS, 1991-2007). Part of this increase can be attributed to enlarged service areas of transit systems.

Exhibit 2.14 Trend in the Number of Public Transportation Trips in East and West Germany (relative to 1992 levels)



Source: (BMVBS, 1991-2007)

2.2.2 Summary of East and West Germany Comparison

In only 15 years, differences in travel behavior between East Germany and West Germany have virtually disappeared. At reunification, motorization levels, mode split, and travel distances were very different in East and West Germany, shaped by 40 years of different transportation and land use. In 1991 West German land use, transportation, and economic development policies were implemented in East Germany. Fueled by reconstruction subsidies for infrastructure investment from West Germany, access to West German currency and automobiles, cutbacks in subsidies for transit in East

Germany, and less government control of spatial development of settlement structure, East German travel behavior became almost identical with West German travel.

2.3 Summary of Germany and U.S. Comparison

In summary, motorization and car use increased rapidly in Germany and the U.S. over the last 50 years, while walking and transit use declined. In spite of these similar trends, there are still large differences in travel behavior and transportation system (see Table 2.6 below).

Americans make more and longer trips per day, travel more kilometers by car and own more cars than Germans. The average American makes 13 percent more trips and travels 62 percent more kilometers per day than an average German. Americans own 41 percent more automobiles and light trucks per 1000 population and drive their cars for 120 percent more kilometers per year than Germans. The share of households with no car in Germany is double the share in the U.S. On the other end of the spectrum, the share of households with two and more vehicles is twice as high in the U.S. as in Germany.

Most trips in the U.S. are made by automobile; walking, cycling, and transit use account for only 14 percent of all trips. Only few U.S. metropolitan areas have an automobile modal split of less than 80 percent for the work trip, but no German city has yet reached that level. Indeed, German cities have an automobile mode split lower than the lowest share for any U.S. metropolitan area.

Cycling is a fringe mode of transportation in the U.S., with a mode split for bicycle use of less than one percent for the nation and in most cities. In Germany almost one tenth of all trips are made by bike, making it a viable mode of transportation. Similarly, walking accounts for two to two and a half times the share of trips in Germany than in the U.S.

The same is true for public transportation, which accounts for less than two percent of all trips in the U.S., but for eight percent in Germany as a whole and for an even higher share in most metropolitan areas.

Both countries displayed similar trends over the last 60 years, but their transportation systems and travel behavior are still very different. There are many potential explanatory factors for these differences. Some of them stem from differences in socioeconomic and demographic factors between the countries. German average salaries and Gross Domestic Product are lower than in the U.S. Additionally, the German population is older, potentially accounting for less travel in general and less car travel in particular. While older people in Germany might drive less, a younger population in the U.S. means a higher share of population cannot drive yet, as they are below driving age.

There are of course also differences in the spatial settlement structure with German cities being more compact, potentially allowing for shorter trips made by foot or bike and sufficient levels of potential transit riders. German cities were rebuilt after WWII and therefore had the chance to accommodate the car as many of the younger U.S. cities did. However, in contrast to the U.S. most German cities were built very densely and suburban sprawl is a more recent phenomenon.

Clearly, there are other factors at work, which shape the land use and transportation system. Policies on all levels of government can account for differences in travel. These differences in policies influence the user costs for the different modes of transportation and have an effect on travel behavior. The tax on gasoline for example is eight times higher (using PPP) in Germany than in the U.S. Higher costs for operating a vehicle, ceteris paribus, lead to less car use. Other policies influencing the price, convenience and time cost of all modes of transportation include: controls and regulation of land use, subsidies for public transportation, regional coordination of public transportation, and local commitment to increasing walking and cycling levels. The next chapter will introduce potential explanatory factors for the differences in travel behavior cited in the international comparative transportation literature.

Table 2.7 Differences in Travel Behavior in the U.S. and Germany, 2000-2002

	U.S.	Germany	U.S. - Germany Difference
Travel Indicators			
Average Number of Trips per Person per Day	3.7	3.3	13 % more trips per person per day in the U.S.
Average Distance Traveled per Person Day (km)	60	37	62 % more km traveled per person per day in the U.S.
Average Trip Distance (km)	16	11.1	44 % longer Average Trips in the U.S.
Automobile Use and Motorization			
Motorization (vehicles per 1000 population)	769	546	41 % more cars per population in the U.S.
Average km of Car Travel per person per Year (km)	24,000	11,000	118 % more km of car travel per person per year in the U.S.
% of Households without Car	8	19	100% lower share of HH without car in the U.S.
% of Households with 2 and more Cars	60	27	100% higher share of HH with 2 or more cars in U.S.
National Mode Shares for All Trips			
% of All trips Made by Transit	2	8	4 times higher share of transit use in Germany
% of All trips Made by Car	86	61	40% higher car share in the U.S. than in Germany
% of All trips Made by Bike	1	9	9 times higher share of bike use in Germany
% of All trips Made on Foot	9	23	2.5 times higher share of walk trips in Germany
Mode Shares in Selected Cities and Metropolitan Areas			
Range Transit Mode Split (%)*	0.6 - 52.7	16.0 - 24.0	2 to 10 times higher transit share in Germany (with the exception of NYC)
Range Automobile Mode Split (%)**	35.0 - 94.3	39.0 - 53.0	On average 50% lower car mode shares in German cities
Range Walk Mode Split (%)***	1.3 - 12.2	20.0 - 26.0	On average 4 to 20 times higher walk share in cities
Range Bike Mode Split (%)	0.1 - 3.5	5.0 - 21.0`	On average 5 to 200 times higher bike shares in German cities

*U.S. data are for worktrips and thus overestimate the share of trips by transit; 52.7% are for work trips in New York City; Washington, D.C., Chicago, and San Francisco have the second highest transit mode shares for work trips at roughly 30%.
** New York City is the only large city with a car mode share of worktrips of less than 50%.
***12.2% for work trips in Boston. The only large city with a walk share of over 10%.

3 International Comparative Research on Travel Behavior

The last chapter has shown that there are large differences in automobile ownership, daily distance traveled, and modal split between Germany and the U.S. This chapter gives an overview of explanatory factors for differences in travel behavior across countries found in the literature.

This literature review begins with a short overview of existing studies comparing travel behavior in Germany and the U.S. in particular and in Western Europe and North America in general. It then provides a typology of these studies based on the methodological approach chosen for the study. The section also highlights differences in definitions and measurements of travel behavior and other variables employed in these studies. The first section (section 3.1) summarizes the state of the art of the literature, the types of studies that exist and the strengths and weaknesses of these bodies of literature. Sections 3.2, 3.3, and 3.4 then go into greater detail on the studies that this dissertation is informed by. The literature review will end with a summary of findings across studies and expected results for the Germany—U.S. Comparison (section 3.5).

3.1 State of the Literature

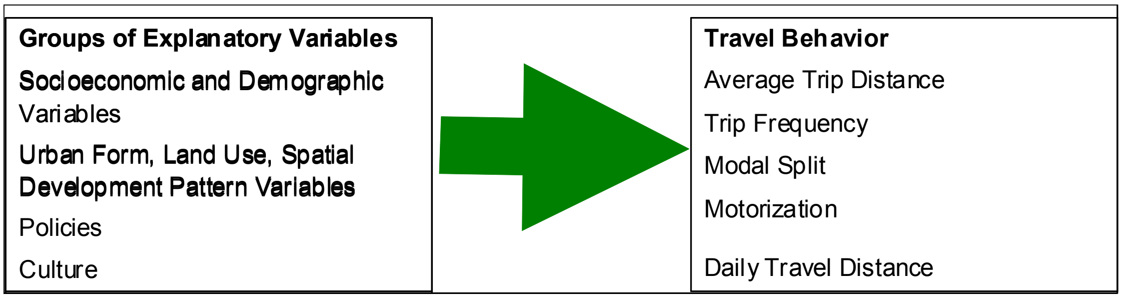
International comparative studies on travel behavior vary greatly in methods, data, units of analysis, and explanatory and dependent variables employed. In general, empirical research on the connection of spatial development, transportation policy, and travel behavior is dominated by U.S. focused studies. Comparatively few empirical studies exist for Germany.

Methodological approaches for comparative studies include descriptive and multivariate statistical analyses. Descriptive studies are mainly case studies of cities, nations, or specific policies over time or at a certain point in time. Multivariate statistical analyses aim to explain or predict rather than describe travel behavior and they are mostly based on observed behavior. Crane (2000) further distinguishes between "*behavioral multivariate models*" with few theoretical assumptions and "*demand models*" with explicit theoretical behavioral frameworks—mainly based on utility maximizing and disutility minimizing behavior. Even though the literature on demand modeling is very advanced it greatly ignores land use and urban form variables (Crane, 2000) and there are only a few international comparative studies that include land use and transportation policies.

Units of analysis in multivariate studies are individuals, households, neighborhoods, cities, and nations. Data employed in these studies generally incorporate cross-sectional, longitudinal, and panel data. The data are usually collected by national or local governments, but occasionally also by researchers directly (e.g. Newman, Kenworthy and Laube's "*Millennium Cities Database*"). Exhibit 3.1 shows the various ways in which travel behavior is measured, as well as groupings of variables used to explain travel behavior. Concepts and measures for travel behavior include passenger kilometers (miles) traveled, trip length, number of trips per day, modal splits, and automobile ownership levels (motorization).

Overall explanatory variables for travel behavior can be categorized as (1) socioeconomic and demographic characteristics, (2) spatial development patterns, (3) policies directly or indirectly affecting travel behavior, as well as (4) national cultures or preferences.

Exhibit 3.1 Groups of Explanatory Variables and Measures of Travel Behavior Commonly Used in the Literature



3.1.1 Only A Few Explicit Germany – U.S. Comparisons

There are only a few studies explicitly focusing on a comparison of travel behavior between Germany and the U.S. The most extensive studies are by Yago (1984) and Pucher and colleagues (Pucher & Chlorer, 1998; Pucher & Dijkstra, 2003; Pucher & Kurth, 1995; Pucher & Lefèvre, 1996). Yago (1984) compares national public transit policies and trends in the U.S. and Germany from 1900 until 1970. His research includes two case studies on the cities of Frankfurt (Germany) and Chicago (USA). Pucher et al. (Pucher & Chlorer, 1998; Pucher & Dijkstra, 2003; Pucher & Kurth, 1995; Pucher & Lefèvre, 1996) analyze land-use policies and trends, transportation policy, and travel behavior on the national and city level[19].

Given the relative shortage of studies explicitly comparing travel behavior in Germany and the U.S. it is useful to enlarge the scope of the literature review to international comparative studies of travel behavior in Western Europe and North

[19] More details on these studies and their authors are presented in the sections that follow.

America in general, that also include components of a Germany – U.S. comparison. Studies with a partial focus on a Germany and U.S. comparison include:

- Nivola's (1995, 1999) international comparisons of land-use policies, transportation and energy use;
- the Transportation Research Board's (2001) special report on transit in Europe, North America and the EU;
- Newman and Kenworthy's (1999) comparisons of mobility in cities worldwide, including German and U.S. cities;
- Banister's (2005) book on unsustainable transportation trends in Europe and the U.S. ;
- Banister et al.'s (Banister, Pucher, & Lee-Gosslin, 2007) article on acceptability of sustainable transportation in North America and Western Europe;
- Vuchic (1999) and Cervero's (1998) books on best practices and city case studies in urban transportation;
- Dunn's (1981) book on travel and policies in Europe and the U.S.

Other studies comparing travel in Western Europe and/or North America are included in this literature review as well. Analysis of these studies will provide insights into travel behavior in the U.S. and Germany compared to other countries, other than a direct Germany—U.S. comparison. The analysis also helps identify a set of variables that may explain international differences in travel behavior.

Table 3.1 below provides a systematic overview of studies published during the last 25 years ordered by date of release. All studies compare travel behavior and explore potential explanatory factors for dissimilarities in Western Europe and North America. The table indicates the authors' names, the units of analysis, methods employed, and the countries studied. The last four columns indicate whether a Germany—U.S. comparison is a central part of the study and if spatial development patterns or transportation policies were mentioned as explanatory factors for travel behavior.

Table 3.1 Selected International Comparative Studies of Travel Behavior in Western Europe and North America

Author	**Year**	**Level of Analysis** – **Aggregate** Nations	City	**Individual Level Data**	**Type of Study** – **Multivariate Statistical**	**Descriptive**	**Countries Analyzed**	**Germany and U.S. Comparison** central	part	**Land Use and Urban Form Component** central	part	mentioned	**Transport Policies** central	part	mentioned
Banister et al.	*2007*	X				X	EU and U.S.		X			X	X		
Giuliano/Narayan	*2006*	X		X	regression		U.S. and UK			X					X
Pucher/Buehler	*2006*	X	X		regression	X	U.S. and Canada				X		X		
Banister	*2005*	X	X			X	EU		X			X	X		
Donaghy/Poppelreuter	*2005*	X				X	EU and U.S.					X		X	
Giuliano/Dargay	*2005*	X		X	probit regression		U.S. and UK				X				X
Stern/Richardson	*2005*	Regions				X	EU Regions					X			
Downs	*2004*	X				X	Worldwide				X			X	
OECD (CEMT)	*2004*	X	X			X	Western Europe and U.S.		X		X		X		
Giuliano/Narayan	*2003*	X		X	regression		U.S. and UK			X					X
OECD (CEMT)	*2003*	X	X				W. Europe U.S. & Russia		X		X		X		
Pucher/ Bansiter	*2003*	X				X	North America, W. Europe		X			X	X		
Pucher/Dijkstra	*2003*	X				X	U.S., NL, Germany	X			X		X		
Simma/Axhausen	*2003*	X		X	SEM*		Germany and Holland								X
Timmermanns et. al.	*2003*		X	X	regression		U.S., J, CAN, UK, NL			X					
Axhausen/Akiva	*2003*	X		X	SEM*		U.S., Austria, CH, UK								X
Kenworthy	*2002*		X		regression	X	Worldwide		X		X			X	
Schwanen	*2002*		X		regression		Western Europe			X					
Gleeson/Low	*2001*	X	X			X	U.S., UK and Australia							X	
Simma/Axhausen	*2001*	X		X	SEM*		Germany, UK, Switzerland								X
Stead Marshall	*2001*									X					X
TRB	*2001*	X				X	W. Europe and U.S.		X		X		X		
Schafer/Victor	*2000*	World regions			linear model		Worldwide					X			
Bratzel	*1999*		X			X	Europe				X		X		
Dargey/Gately	*1999*	X			regression		Worldwide								
Giuliano	*1999*	X				X	W. Europe and U.S.			X				X	
Ingram and Liu	*1999*	X	X		regression		Worldwide								X
Newman/Kenworthy	*1999*		X		regression	X	Worldwide		X		X			X	
Newman et al.	*1999*		X		regression	X	Worldwide		X		X			X	
Nivola	*1999*	X				X	OECD		X	X				X	
Vuchic	*1999*	X	X			X	W. Europe, U.S. and CAN		X		X			X	
Button	*1998*	X				X	Europe and U.S.					X	X		

Continues on next page

Cervero	*1998*		X			X	W. Europe and Canada		X		X		X		
Pucher	*1998*	X	X				Germany and U.S.	X			X		X		
Schafer/Victor	*1997*	X				X	Worldwide					X			X
Newman et al.	*1996*	X	X			X	Worldwide				X			X	
Pucher/Lefevre	*1996*	X				X	W. Europe U.S. and CAN	X			X		X	X	
Nivola	*1995*	X				X	W. Europe, U.S. and CAN		X		X			X	
Pucher	*1995a*	X	X			X	Europe and U.S.	X			X		X		
Pucher	*1995b*	X	X				Europe and U.S.	X			X		X		
Pucher/Kurth	*1995*	X	X				Europe					X	X		
Clark/Kjippers	1994		X			X	U.S. and Netherlands								
Hass-Klau	*1993*	X	X			X	Western Europe				X		X		
Orfeuil	*1993*	X				X	Western Europe		X		X			X	
Pucher	*1994*	X	X			X	Canada and U.S.				X		X		
Newman/Kenworthy	*1989*		X		regression		Worldwide		X	X				X	
Pucher	*1988*	X				X	Germany and U.S.	X				X		X	
Yago	*1984*	X				X	Germany and U.S.	X				X		X	
Dunn	*1981*	X				X	W. Europe and U.S.		X		X		X		

*SEM=Structural Equation Modeling

Note: Studies which simply assemble and present country studies without a comparative analysis were excluded.

Sources: (Axhausen et al., 2003; Axhausen & Simma, 2001; Banister, 2005; Banister et al., 2007; Bratzel, 1999; Button, 1998; CEMT, 2003, 2004; Cervero, 1998; Clark & Kuijpers-Linde, 1994; Dargay & Gately, 1999; Donaghy & Poppelreuter, 2005; Downs, 1999; Dunn, 1981; Giuliano, 1999; Giuliano & Dargay, 2005; Giuliano & Narayan, 2003, 2004, 2006; Gleesen & Low, 2001; Hass-Klau, 1993b; Ingram & Liu, 1999; Kenworthy, 2002; Newman, 1996; Newman & Kenworthy, 1999; Newman, Kenworthy, & Laube, 1999; Nivola, 1995, 1999; Pucher, 1988, 1994, 1995a, 1995b; Pucher & Banister, 2003; Pucher & Buehler, 2006; Pucher & Chlorer, 1998; Pucher & Kurth, 1995; Pucher & Lefevre, 1996; Schafer, 1999; Schafer & Victor, 1997, 2000; Schwanen, 2002; Simma & Axhausen, 2003; Stead & Marshall, 2001; Stern & Richardson, 2005; Timmermanns et al., 2003; TRB, 2001; Vuchic, 1999; Yago, 1984)

3.1.2 Dominance of Descriptive and Aggregate Level Analyses

Table 3.1 above and Table 3.2 below show that 34 out of 50 international comparative studies used descriptive rather than multivariate statistical analyses, conducted more often than not on aggregate data at the city, state, or national level (43 out of 50).

Table 3.2 Overview of Studies included in the Literature Review, by Type of Study, Unit of Analysis, and Focus of Study

International Comparative Studies of Travel Behavior Included in the Literature Review, by Type of Study and Unit of Analysis			
	Descriptive	Multivariate	
Individual Level Data	0	7	7
Aggregate Data	34	9	43
	34	16	50
International Comparative Studies Inculding a Germany - USA Comparison, by Type of Study and Unit of Analysis			
	Descriptive	Multivariate	
Individual Level Data	0	0	0
Aggregate Data	19	4	23
	19	4	23
International Comparative Studies of Travel Behavior Focusing on Germany and the USA, by Type of Study and Unit of Analysis			
	Descriptive	Multivariate	
Individual Level Data	0	0	0
Aggregate Data	7	0	7
	7	0	7

Most of the descriptive studies relate differences in travel behavior to socioeconomic variables, policies, and best practices in nations as a whole or on the city level (see e.g. Pucher & Lefevre, 1996; Cervero, 1998; Newman and Kenworthy, 1999; Banister, 2005). Aggregate national comparisons describe the influence of national policies, aggregate socioeconomics, and land use trends on travel behavior. They make educated inferences about explanatory factors for different travel behavior. Case studies of cities or policies mainly focus on the local level and describe best practices or successful policies (e.g. Cervero, 1998; Bratzel, 2000). In most cases these analyses cannot be supported by with multivariate methods, as the number of observations is too small. There are some exceptions however.

Newman, Kenworthy, and Laube (1999) used their "*Millennium Cities Database*" for multivariate statistical analyses comparing aggregate data for 100 cities worldwide. Other exceptions include studies by Schafer and Victor (2000), Ingram and Liu (1999), and Dargay and Gately (1999), which all used regression analyses based on national aggregate data from countries worldwide.

Describing national policies and aggregate comparisons of nations and urban areas is important, but these studies have two main shortcomings. First, comparisons across averages hide variation within different parts of countries and within different locations in a metropolitan area. Second, aggregate studies cannot give insights into individual travel behavior and decision making. The decisions on what transportation mode to choose and how far to travel are made by individuals within their individual circumstances. Variables such as income, car ownership, access to transit, land uses, pricing, and other policy measures can vary widely among people and within countries (Giuliano & Narayan, 2004). If adequate data exists, multivariate statistical analyses with individual level data are able to best capture observed individual behavior (Crane, 2000). Comparable data is often not available however.

More recently a few studies have emerged, which attempt to compare travel behavior internationally using individual level data and multivariate statistical analyses;

but overall only little work has been done in this area (Axhausen et al., 2003). These studies include Giuliano's (2005; 2003, 2004, 2006) work comparing travel in the UK and the U.S. She and her colleagues use a random sample of individuals from national travel surveys in the UK and the U.S. for the year 1995 and conduct linear and non-linear regression analyses. Three studies by Axhausen and colleagues (2003; 2001; Simma & Axhausen, 2003) compare travel behavior and commitment to a certain mode of transportation in Holland, Switzerland, England, Germany and the U.S.[20] For their analyses the researchers rely on Structural Equation Modeling (SEM). Timmermans and colleagues (2003) compare travel behavior across different metropolitan locations (center/suburb) of North American, Japanese, British and Dutch cities using regression analysis.

All of these multivariate studies, no matter if they are on the national or regional scale, are plagued by incomparability either in data or in data collection methods. Due to these limitations they often cannot capture all desired variables or have to rely on strong (often unrealistic) assumptions about the comparability of their data (Axhausen et al. 2003).

The set of explanatory variables used in many comparative studies also remains incomplete. For example, Giuliano and colleagues made an effort to specifically include variables describing spatial development patterns and land use as explanatory variables for travel behavior in a multivariate statistical analysis comparing the U.S. and the UK; but even these researchers fail to include policy variables in their models.

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[20] The analysis of Germany and the U.S. are part of two different studies, comparing each country to other countries, using different datasets and different variables at different points in time.

Overall, there has not been any study comparing travel behavior in Germany and the U.S. during the last 10 years. Moreover, no study has ever used individual level data for a comparative multivariate analysis of travel behavior in Germany and the U.S. The following sections give a more detailed overview of literature on international comparative travel behavior, starting with results produced through multivariate statistical analyses, followed by those obtained from descriptive analyses.

3.2 Multivariate Statistical Analyses

As mentioned above, multivariate analyses vary according to units of analysis, methods, data, and the stringency of behavioral assumptions in the models. This section first introduces studies using aggregate level data, such as nation-wide, city-wide or TAZ (travel analysis zone) wide averages. Aggregate studies hide variation among individuals and across geographic areas. This limitation is overcome by individual level analyses, as explained below in section 3.2.2. Two tables, at the beginning of each section, summarize dependent and independent variables, as well as units of analysis, and year of publication for the multivariate studies that use aggregate and individual level analyses presented in the next two sections.

3.2.1 Studies Using Aggregate Level Data and Their Shortcomings

Table 3.3 below summarizes international comparative studies using aggregate level data. Schafer and Victor (2000) tried to predict and compare the future mobility of the world population using linear and non-linear multivariate models. Their study was based on time series data from 1960-1990 and employed aggregate level average travel indicators of 11 world regions. Their two dependent variables were average miles traveled per person and the mode share of travel. Even though daily travel distance was larger in higher income regions they found constant travel time and monetary budgets (percent of income) for travel in all world regions. This indicates that, ceteris paribus, as income increased miles of travel per person and the share of trips by automobile increased. Faster modes became affordable with higher incomes and allowed covering further distances in a given amount of time. Differences across world regions were explained through supply of transportation infrastructure, historically developed land-use patterns, population densities and varying cultures across world regions. But these intervening factors were not included in their multivariate statistical analyses. Shortcomings of their study included a lack of intra-regional differentiation between urban and rural travel as well as missing information on the number of trips or the lengths of average trips.

Table 3.3 International Comparative Multivariate Statistical Analyses with Aggregate Data

Author	Year	Dependent Variables	Explanatory Variables				Time
			Socioeconomics	Urban Form/Land Use	Policy	Culture	
Pucher/Buehler	2006	bicycle mode share	car ownership	average trip distance of work trip	gas price, cycling fatality rate	dummy variable	2000 (US), 2001 (CA)
Kenworthy	2002	transport energy use, transport emissions	GDP per capita, vehicle ownership	depopulation density, job density, % jobs in CBD	roads, parking, transport investment and spending, congestion, transit service/speed, transport fatalities		early 1990s
Schwanen	2002	distance, time, mode share	GDP per capita, vehicle ownership	population size, population density, share of population in central city, share of businesses in CBD			1960-1990
Stead/Marshall	2001	trip distance, journey frequency, modal split, travel time, transport energy consumption	income, car ownership, license, age gender, HH size, work status, educational level	distance of residence from the urban center, settlement size, mix of land uses, provision of local facilities, density of development, availability of residential parking, proximity to transport network, road-network type, neighborhood type		attitudes	International review of mainly national studies from 1983 - 1999
Schafer/Victor	2000	miles traveled, mode share	time budget, monetary budget	mentioned but not in multivariate analysis			1960-1990
Newman/Kenworthy	*1999*	transport energy use, transport emissions	GDP per capita, vehicle ownership	depopulation density, job density, % jobs in CBD	see Kenworthy 2002		early 1990s
Newman/Kenworthy/Laube	*1999*	transport energy use, transport emissions	GDP per capita, vehicle ownership	depopulation density, job density, % jobs in CBD	see Kenworthy 2002		early 1990s
Ingram and Liu	*1999*	vehicle ownership, road length	national income	control for urban areas vs. national			1987
Dargey/Gately	*1999*	car/population ratio, vehicle ownership	per-capita income				1960-1992
Newman/Kenworthy	*1989*	transport energy use, transport emissions	GDP per capita, vehicle ownership	depopulation density, job density, % jobs in CBD	see Kenworthy 2002		1980s

Similarly, Ingram and Liu (1999) synthesized prior studies relating income, car ownership, and the length of paved roads in countries and cities all over the world through regression analyses. They used data for countries and cities worldwide for the year 1990. They found that income is a good predictor of car ownership and road length. The richer a country the more cars and the more roads it had. For cities they found that growing incomes and car ownership are closely related, while the growth of the length of urban roads and income are less closely connected. They combined their findings from cross-sectional data with historical income elasticities found through a literature review. They then went on to estimate future greenhouse gas emissions of the transportation sector in various countries until 2025. The only spatial variable the researchers used is a differentiation between the nation as a whole and urban areas.

In another worldwide study, Dargay and Gately (1999) used regressions to predict car and vehicle ownership in 26 countries for the year 2015. Their estimates were based on 1960-1992 time series data from various countries. They found a strong relationship between income and motorization rates. Additionally they estimated that car ownership levels will converge in OECD countries in the future, implying slower growth in the U.S. compared to Western Europe.

Newman, Kenworthy, and Laube (1989, 1999; 1999; 1996) conducted several analyses of cities worldwide relating average income, urban structure, population density, and transportation infrastructure supply to energy consumption within the transportation sector. They found that higher urban density was negatively related with per capita energy consumption for the transportation sector. They also showed that income was not linearly related with car use. According to their results high income European and Asian cities exhibited less car use than American and Australian cities with lower incomes. They also found that land use and transportation infrastructure supply had an impact on transportation energy use. The lower the population and workplace density of a city was the more road supply per inhabitant they found. The lower levels of transit supply were, the higher was the level of energy consumption in the transportation sector.

These studies were heavily criticized by other scholars such as Gomez-Ibanez (1991), for methodological and measurement problems, but also for not including crucial data on individual income, taxation of gas and car ownership, and transit fares and subsidies. Gasoline consumption as dependent variable and indicator for automobile dependence was not an ideal variable as it did not account for automobile technology. Furthermore they did not include energy use for non-road based modes of transportation. Gomez-Ibanez also pointed out that Newman and Kenworthy did not account for the benefits of automobile use and they failed to include direct and indirect effects in their statistical models. The results of the weaknesses –according to Gomez-Ibanez—were unconvincing conclusions and policy recommendations.

Schwanen (2002) compared the influence of land use and urban form on commuting in Europe. He used time series data collected by Kenworthy and colleagues ("*Millennium Cities Database*") for 11 European cities from 1960 to 1990. He argued that research on the land use transportation connection had been neglected in Europe and that most empirical findings were based on studies from the U.S. He measured travel behavior as average commuting distance, average commuting time, and modal split for the trip to work. His land use and urban form variables were population density, the ratio of population in the inner city vs. the city as a whole, the proportion of jobs in the CBD

(Central Business District) and population size of the metropolitan area. His regression analysis controlled for the influence of the gross regional product (GRP) on travel. He finds that cities with higher GRPs had longer commute distances, slightly shorter commuting times and a higher share of automobile use. Higher population densities were related to shorter commuting distance and time and higher modal splits for non-automobile travel. Transit use decreased and walking and cycling increased if a large amount of population was concentrated in the city center. Overall he found great variability among European cities and a tension between transit use versus walking and cycling, as they competed for mode share against each other, not only against the automobile. Disconnected from his empirical findings he argued that European travel, compared to the U.S., was driven by the location of employment and residential areas within a metropolitan area.

Pucher and Buehler (2006) compared the level of cycling for the work trip in Canadian provinces and U.S. states. Using both linear and log-linear regression analyses, they found that the price of a liter of gasoline, urban density, mix of land uses, cycling safety, and differences in temperature and precipitation explained about 60 percent of the variability of cycling levels across states and provinces. Furthermore they found that a dummy variable indicator for U.S./Canada differences did not play a statistically significant role in explaining cycling levels.

Stead and Marshall (2001) provide an international overview and critique of empirical studies linking urban form and travel behavior. They surveyed studies from the U.S. and Western Europe and compared the findings. With few exceptions, the papers included in the study were not international comparative studies. However the influence of urban form and land use on travel behavior in Europe and the U.S. was consistently found, even when other factors are accounted for.[21]

They found that urban form was conceptualized in nine different ways across the studies surveyed: (1) distance of residence from the urban center, (2) settlement size, (3) mix of land uses, (4) provision of local facilities, (5) density of development, (6) availability of residential parking, (7) proximity to transportation network, (8) road-network type, and (9) neighborhood type. Precise measurements for urban form varied within these categories. They reported that the empirical literature in general conceptualized travel as (1) trip distance, (2) journey frequency, (3) modal split, (4) travel time, and (5) transportation energy consumption.

On the connection of land use and transportation, Stead and Marshall found that travel distances and energy consumption of transportation in general increased as the distance of a residential location to the city center increased. Evidence for the influence of settlement size on travel was inconclusive, but some studies showed shorter trips for more populous urban areas. The effect of the mix of land use on travel depended on the measure of travel behavior employed; for example different effects were found on mode share and on trip distance. The provision of local facilities (shops, jobs etc.) resulted in less travel overall, but did not necessarily contribute to an increase in walking and cycling. Many studies suggested a link between population density and travel behavior, but employment density had been neglected in studies so far. All else equal, easy access to rail or highway networks increased travel distances. Most studies suggested more

[21] The relative weight of land use factors seems to be weaker than for socioeconomic and demographic variables.

transit use, walking and cycling in older and more densely built neighborhoods compared to more car use in suburban neighborhoods; but no causality had been established.

Stead and Marshall (2001) identified several weaknesses of existing studies in their survey. First, they found that the use of average trip distance data on the aggregate level (e.g. for metropolitan areas or travel zones) misinterpreted actual trip distances, which varied across individuals. This problem was overcome by individual level analyses presented in the next section.[22] Second, the commonly used self-completed surveys were likely to understate short trips and overstate household travel overall, because individuals did not report their short trips accurately and assumptions about travel of all household members were made based on a few respondents in the household. Third, the lack of controls for socioeconomic factors in the studies weakened the connections found. Controlling for socioeconomic factors of the neighborhood or the trip maker was difficult as variables on socioeconomics were often correlated with each other (e.g. income, car ownership, license ownership, age, gender, household size, work status, educational level, and attitudes about transportation options). Fourth, potential multicolliniarity of land use and urban form variables was common in the studies. Similarly, TRB (1996) reported that land use mix and urban design in the U.S. were highly correlated with density. TRB even suggested that once density is taken into account design and mix cannot add much explanatory power.

3.2.2 More Recent Studies: Using Individual Level Data

A summary of more recent studies comparing international travel behavior based on individual level data is presented in Table 3.4 below. In a series of studies comparing the United States and the United Kingdom Giuliano and Narayan (2003, 2005, and 2006)

[22] All studies presented in the next section were conducted after Stead and Marshall's article was published.

explored the connection of urban form, population density and travel behavior. A random sample of 20,000 individuals was drawn from the Nationwide Personal Travel Survey (NPTS) 1995 for the U.S. and the National Travel Survey (NTS) 1995 for Great Britain; with 10,000 individuals selected from each country. They used a linear regression model for their analyses (2003 and 2006) and their dependent variables measuring travel behavior were trip distance and trip frequency. Metropolitan size and population density at place of residence were indicators for spatial development patterns. They controlled for age, household income, employment status, and number of cars per household. The overall R^2, the percentage of variability in the dependent variable explained by the independent variables, was 7.6 percent for the dependent variable "*trips per person per day*" and 25 percent for "*total distance of daily trips per person*".

They found that socio-economic and urban form variables worked the same way in the U.S. and the United Kingdom. Minor differences existed, but could be explained via differences between the countries, e.g. lower incomes and more traditional gender roles in the UK than in the U.S. Car ownership was an important factor in both countries in explaining travel distance and number of trips per day. Metropolitan size had a small effect on trip distance and frequency. The larger an MSA was the longer the trips were. Higher residential densities were associated with shorter trip distances in the U.S., but not in the UK.

Table 3.4 International Comparative Multivariate Statistical Analyses with Individual Level Data

Author	Year	Dependent Variables	Explanatory Variables				Time
			Socioeconomics	Urban Form/Land Use	Policy	Culture	
Giuliano/Narayan	*2006*	trips per day, miles of travel per day	sex, age, income, employment status, car ownership, car/driver per HH ratio	MSA size, population density	descriptive: gas price, tax, housing policy	dummy variable	1995 (US), 95/97 (UK)
Giuliano/Dargay	*2005*	car ownership, miles traveled	sex, age, employment status, HH size, income, lifecycle HH, cars per HH	residential Density, MSA size, distance to transit, house/apartment	dexscriptive: car ownership and operating costs	dummy variable	1995 (US), 95/97 (UK)
Giuliano/Narayan	*2003*	trips per day, miles of travel per day	sex, age, employment status, income	residential Density, MSA size		dummy variable	1995 (US), 95/97 (UK)
Simma/Axhausen	*2003*	car or transit trips per day	sex, age, employment status, HH size, car availability, transit season ticket owner, driver's license dummy	urban/rural dummy			1994-1998 (D), 1984-1989 (NL)
Timmermanns et. al.	*2003*	trips, tours per day	transport mode, income, HH size	urban/suburban indicator, transit access indicator			94 (US, 93 (J), 92 (CA), 94 (UK, 97 (NL)
Axhausen/Akiva	*2002*	cars per adulst per HH, daily trips, daily travel time	wroker/not worker dummy, HH size, sex	urban/rural indicator			1994(A, CH), 95 (US), 96-98 (UK)
Simma/Axhausen	*2001*	trips per day by car/transit, miles traveled by car transit	sex, age, employment status, car availability, transit season ticket owner dummy, # of children	urban/rural indicator			1994 (CH), 99 (UK), 94,95,96, 97, 98 (D)

Based on the same data Giuliano and Dargay (2005) employed a structural model to disentangle the connection of land use, car ownership and travel. In a first stage they modeled the household's decision on car ownership (0, 1, 2, or 3 and more cars) and in a second stage they modeled travel behavior. This two step model allowed them to identify the direct effects of the independent variables on travel and the indirect effects resulting from the household's decision on automobile ownership. Alongside that structural model they used a simple linear model omitting the car ownership variable altogether. Interestingly, the two models yielded very similar results and the explained variability is 16 percent for both models.

The only major difference was a stronger influence of population density on travel once car ownership was removed, which indicated a connection between dense areas and car ownership. They had not expected these similar results from the two divergent models. They conclude that car ownership was probably connected to variables not directly measured in their model, such as the costs of operating and owning a car. If car ownership was correlated with variables not included in the model then car ownership was correlated with the error term of their regression equation.

Ironically they resorted to public policy variables as explanatory factors, even though Giuliano (e.g. 2003) had regularly pointed out that public policy only had little or no influence on travel. Overall, their findings were similar to the results of Giuliano and Narayan presented above. So far, no study on the individual level has successfully included transportation policies and land use/urban form variables.

Three studies by Axhausen and colleagues (2001, 2002, and 2003) compared travel behavior and regular use of either transit or the car in Holland, Switzerland, England, Germany, and the U.S.[23] The studies employed different data sources including large national travel surveys and smaller datasets consisting of national and regional panel data for the time period 1994-1998. Timing, methods and data varied across the countries. To overcome differences in data and methods they relied on strong assumptions concerning the comparability of their data and results. The method used was Structural Equation Modeling (SEM). Similar to Giuliano and Dargay's structural approach this method allowed them to distinguish between *direct effects* of certain variables on travel and their *indirect effect* via other variables (e.g. the effect of income on travel and the indirect effect of income on travel through car ownership). They found some common sense patterns that were stable across countries, such as: (1) the more cars a household owned the more trips its members made; (2) higher incomes were associated with higher car ownership levels; (3) transit was used especially in cities. Their only variable related to spatial development patterns was an urban vs. rural distinction, which yielded lower automobile ownership levels in cities compared to rural areas. The only policy variable they used was transit season ticket ownership, which is related to more transit use.

Timmermans and colleagues (2003) compared the relationship of urban spatial development patterns, access to public transportation and travel behavior across five cities or regions in five different countries (Portland (USA), the Midlands Region (UK), Fukuoka (Japan), the South-Rotterdam Region (Holland) and data from unidentified Canadian metropolitan areas). The regions were not representative for the respective country, however. The authors measured travel behavior as either number of trips

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[23] The analysis of Germany and the U.S. are part of two different studies, comparing each country to other countries, using different datasets and different variables at different points in time.

starting and ending at home, so called home based tours, or as number of trips per day. Their control variables were socioeconomic and demographic information on the household level. They found that the number of home based tours did not vary considerably across income groups, but that single male households with children displayed a higher number of home based tours per day. They also found that single females made on average the most trips per day of all demographic groups. Looking at different transportation modes used, the number of daily home-based tours was higher for bus users than for any other mode. None of the spatial context variables was significant in explaining differences in the number of home-based tours or the number of trips. Even though not part of their analysis, they concluded that within a society "*psychological principles*" seemed to be more important in explaining travel behavior than measurable characteristics included in their analysis.

In summary, multivariate statistical analyses were very powerful in establishing empirical connections, especially when they were based on individual level data. Unfortunately, the strict methodological, statistical and data quality requirements imposed by the models prevented inclusion of important variables and sometimes biased the results. Variables relating to public policies and also to spatial development patterns were very often omitted from the models, or when included, resulted in mixed, inconsistent or unexpected results. Most importantly, testing the connection between transportation and spatial development patterns, while controlling for socioeconomic and demographic data, has produced mixed results and is still inconclusive for international comparative studies. There were no individual level studies that simultaneously include socioeconomics and demographics, urban form and policy variables.

3.3 Descriptive Studies

In contrast to multivariate statistical analyses descriptive studies were not limited by strict data comparability requirements and assumptions of the statistical method chosen. They provided a rich picture of potential explanatory factors for travel behavior. These studies were mainly thorough descriptions of case study cities, nations, or specific policies. In contrast to multivariate analyses a plethora of explanatory factors could be explored without the constraints imposed by multivariate models, such as multicoliniarity or data comparability problems. Similar to the statistical analyses presented above descriptive studies also investigated socioeconomic factors and land use variables, but they also included variables that are not easily measurable for multivariate analysis, such as policies, politics, or culture. The following gives a brief overview of international comparative descriptive studies, ordered by year of publication.

Dunn (1981) compared transportation policy in European Countries and the U.S. He found that public sector financing priorities for certain modes of transportation, the scope accorded to market forces, and the level of government authority in the transportation sector were distinguishing factors. Overall he characterized the European approach to transportation as more top-down and more reluctant about infrastructure enlargements than the U.S. approach. According to Dunn Europeans put a greater emphasis on the social costs of transportation. Europe has had an older settlement structure with a stronger emotional attachment of its citizens to the place of residence, which was incompatible with the construction of "*excessive*" transportation capacity. Overall Europeans were more willing to readily accept government taxation and mandates. In the U.S., on the other hand, transportation investments were seen as an end in themselves by creating jobs. There was little or no coordination of land use, housing and transportation policy in the U.S.

Yago (1984) compared the decline of public transportation in Germany and the U.S. between 1900 and 1970 from a political economy perspective. He used aggregate level data to highlight changes in urban transportation and the national economy as a whole over time. This included trends in Gross Domestic Product (GDP), importance of the transportation sector for the national economy, transit ridership and motorization levels as well as road and transit infrastructure construction and subsidies. Additionally, he compared the power of transportation industries and social classes over national governments and resulting differences in policies towards the economy as a whole, and transportation and land use in particular. He illustrated these changes in two case study cities: Frankfurt, Germany and Chicago, U.S.

His historical analysis focused on economic development, politics and especially the changes in class based access to political power. Of special interest were the power struggle of different social classes and the power of private transportation industries to influence local and national policy making. These two were his main explanatory factors. Differences in transportation in the two countries could be attributed to changes in the power of transportation industries and/or social classes in respective times. The earlier and stronger decline of transit in the U.S. was attributed to "*changes in corporate power and variations in the timing and form of government intervention in urban transportation policy and planning*" (Yago, 1984, p. 176). Even though his focus was on politics Yago did not discount the influence of policy and technological changes on transportation development and urban form. He provided a rich description of policy and technological changes in both countries, which he interpreted as the result of changing industrial and class access to power in both countries over time.

Pucher and colleagues (1988, 1995, 1996, 1998, and 2003) compared urban transportation in Europe and North America. The focus of their descriptive empirical analyses was on public policies as shaping factors for transportation supply, demand, and spatial development patterns. The unit of analysis was mainly the nation state or occasionally cities. They compared aggregate averages of travel behavior, transportation supply and demand, and land use across countries over time. They identified a series of main contributing factors for the differences in travel behavior in Germany and the U.S. these factors included: higher transit service supply, earlier government subsidies for public transportation, more and safer bicycling infrastructure, more extensive traffic calming, integration of transportation and land-use planning, increased and safer pedestrian facilities, higher costs of car ownership and use, such as higher costs of parking and taxes on gasoline, more extensive and expensive training for obtaining a driver's license, less supply of roadways, more restrictive land-use policies, and a later mass marketing of the automobile in Germany. Pucher (1988) made the point that higher income in the U.S. did not necessarily explain more automobile ownership and use. At the time of study, West Germany, Sweden and Switzerland had higher per capita incomes at the time than the U.S. Compared to the U.S., these countries pursued policies that discouraged car use and encouraged alternative modes, such as higher gasoline taxes or more subsidies for public transportation. According to Pucher and colleagues, public policies, programs and financing/subsidies played a central role in affecting travel behavior and explaining differences in travel behavior internationally.

Nivola (1995, 1999) compared land use and energy consumption in Europe and North America. He found that higher levels of car use and low density developments were not solely attributable to U.S. geography or economic factors, but rather to policies shaping costs of car use and suburban development. He found that 2/3 of all U.S. vehicle miles traveled (VMT) were on urban roads and that 90 percent of all trips were shorter than 10 miles long, therefore suggesting that geography could not be the main factor behind high U.S. VMT. He identified higher taxation of automobile ownership and use, a longer tradition of transit subsidies, a more favorable ratio of transit vs. road funding, and a more stringent land-use planning system with less competition among states and municipalities in Germany as the driving factors behind comparatively lower levels of sprawl and car use in Germany than the U.S. He acknowledged that the development pressure for accommodating new housing and industries was much larger in the U.S. than in Germany. From 1950 to 1996 the U.S. population increased by 70 percent, while Germany's population only grew by 20 percent.

Bratzel (1995, 1999, 2000), Cervero (1998) as well as Vuchic (1999) compared best practices in transportation and land-use policy and planning in European and North American cities. Besides his analyses of policies, Bratzel (1999) found that opportunities for promoting sustainable transportation presented themselves as an outcome of a crisis or were caused by other external factors. The success for implementing sustainable policies then depended on the local circumstances present when external pressures occur, such as active citizen groups pushing for certain policies. Cervero (1998) and Vuchic (1999) presented case studies of cities in North America and Europe and found that policies affecting automobile transportation demand, combined with land-use policies could be effective in reducing automobile travel. Demand-side policies included pricing for gasoline and parking. Traffic-calming and land-use measures included dense development around transit stops and mixed-use development with pedestrian friendly design.

Button (1998) compared transportation policy, potential lessons learned, and transferability of policies in Europe and the U.S. He found that both the EU and the U.S. had made efforts to liberalize their transportation markets. Main distinguishing factors were the integration of land use and transportation planning in Europe, the greater acceptance of government intervention and the more limited geography of Europe.

The Transportation Research Board (TRB) (2001) compared public transportation in the U.S. and European countries. They found that historical factors in timing and extent of motorization, transit subsidies and taxation on automobile ownership and use, and stricter land-use policies explain differences in travel in the U.S. and Europe. Additionally, current policies and programs in Western Europe were aimed at increasing the attractiveness and convenience of transit while limiting car use. This "*carrot and stick*" approach was not used in the U.S., where restrictions on car ownership and use were less frequently found.

Banister and colleagues (2007) compared sustainable transportation in Europe and North America. They found that the U.S. did not use taxation to discourage car use, had deregulated transportation markets, and emphasized efficiency over equity in the transit market. Weak land-use policies and relatively little emphasis on encouraging and funding rail and local public transportation resulted in relatively unsustainable transportation. The U.S. federal government intervened in transportation markets mainly via subsidies for infrastructure construction or regulation, such as the Corporate Average Fuel Standards (CAFE). Europe on the other hand used more of a top down approach to transportation, with governments intervening more strongly.

In summary, descriptive studies emphasized the importance of public policies in shaping travel behavior. Policies provided incentive structures and opportunities for the use of different transportation modes. European policies made car travel less attractive while providing ample opportunities for other modes of transportation. Policies that restricted car use in Europe were higher costs of owning and operating an automobile, comparatively less supply and funding for roads, restrictions on car use through traffic calming or pedestrian only schemes, and less free parking supply. Transit on the other hand was a more viable mode of transportation in Europe as it was better funded, the rolling stock was more attractive, transit service was better integrated and there were higher levels of transit service. Cycling and walking levels were higher in Europe, because of more cycling facilities and pedestrian zones, and higher safety for pedestrians and cyclists. Altogether Europeans countries were found to have stricter land-use controls, better integration of land use and transportation planning, a higher willingness from citizens to accept government intervention and more collectivist attitudes.

3.4 Summary and Predicted Differences and Similarities in Germany and the U.S.

Overall, socioeconomic and demographic factors have been well established as explanatory factors for travel behavior in the literature. The question examined here was not *whether* they should be included as categories in modeling travel behavior, but *how* they should be used. Results of studies on the impacts of land use and spatial development variables on travel were mixed (Handy, 1996). While their connection to transportation seems logical, the empirical evidence remained vague and unclear, especially in international comparisons. Policies were included in most studies on travel behavior, but rarely explicitly modeled in international comparative multivariate studies. Even though some authors contested the importance of policies altogether, there has been a growing consensus that policies play a role in shaping travel behavior. Cultural differences were difficult to measure, but many authors allude to cultural differences in shaping spatial development, policies, and travel behavior.

The following section provides a summary of measures of travel behavior and four groups of explanatory factors: (1) socioeconomics and demographics, (2) spatial development patterns, (3) transportation and land-use policies, and (4) culture. For each explanatory factor the expected contribution for explaining differences in travel between Germany and the U.S. is explained.

3.4.1 Dependent Variables: How to Measure Travel Behavior?

Concepts and measures most frequently used for travel behavior were motorization, mode choice, and intensity of mode use (see Exhibit 3.2). Motorization was measured as cars or vehicles per household or individual, or as cars per 1,000 population. Mode choice was captured by percentage of trips by type of mode and purpose, such as work trip, leisure, shopping, or all trip purposes. The intensity of mode use was quantified as total daily distance traveled by each type of transportation, average trip distance, and passenger miles of travel or number and frequency of trips. Travel speed and energy use by the transportation sector were also used to capture travel behavior. The former was a combination of widely used measures of distance and time. The choice of travel indicator, mode choice, motorization, or travel intensity may lead to different results. While daily trip frequency and daily travel time have been found to be relatively constant, trip distance and mode choice vary considerably across individuals, cities, countries and over time.

Exhibit 3.2 Commonly used variables for capturing travel behavior in the literature reviewed

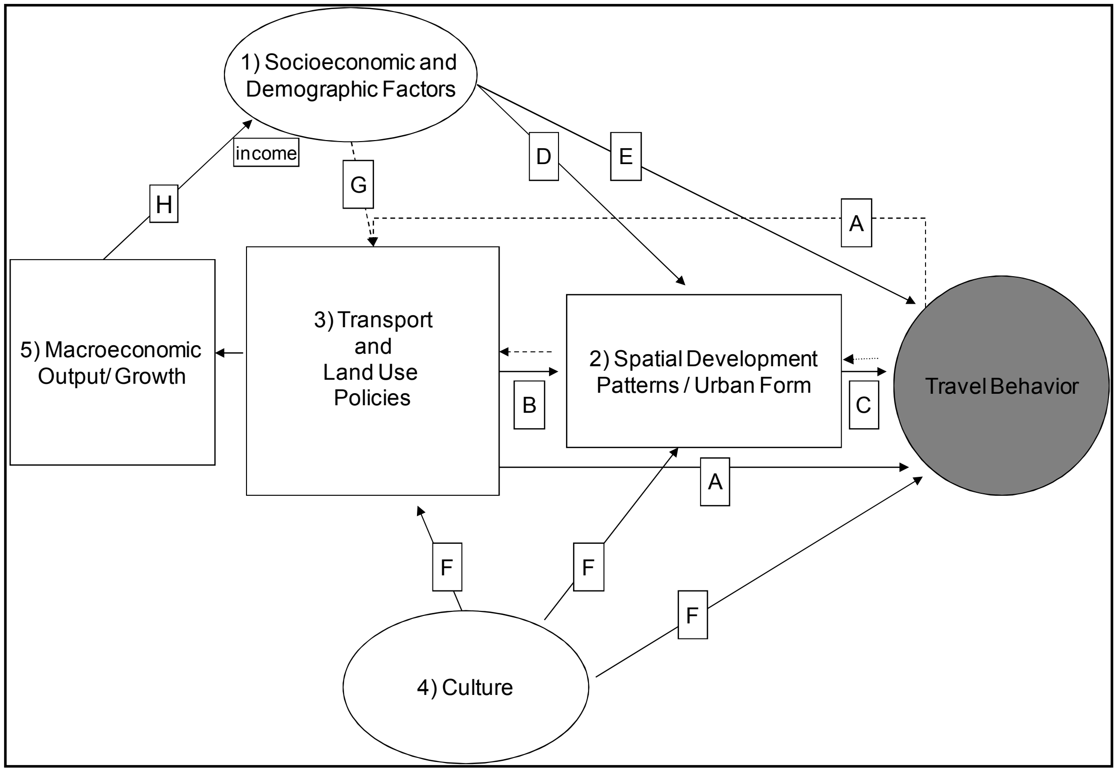
- Trip length
- Total daily/annual distance traveled
- Trip frequency
- Modal split
- Automobile ownership levels
- Travel speed (distance divided by time)
- Energy use of transportation sector

3.4.2 Independent Variables: Four Categories

Explanatory variables for travel behavior for international comparisons can be grouped into: (1) individual characteristics (socioeconomic and demographic variables); (2) spatial development patterns; (3) transportation and land-use policies and infrastructure supply; and (4) culture.

The relationship between the groups of explanatory factors is complex and depicted in Exhibit 3.3 below. The only truly independent (exogenous) factors are socioeconomics, demographics, and culture. Transportation and land-use policies, spatial development patterns, and travel behavior are all influencing each other, and/or are influenced by socioeconomic factors and culture.

Exhibit 3.3 Expected Relationship of Explanatory and Dependent Variables



Transportation and land-use policies influence travel behavior directly, via pricing of gasoline or the supply of roads and public transportation services (Arrow A); and indirectly by prescribing development purposes for certain areas of the city (Arrow B). Spatial development patterns influence travel behavior by providing mobility and accessibility to destinations by certain modes (Arrow C). Mixed-use areas tend to reduce distances to activities, while higher densities tend to reduce automobile speeds, due to congestion. Travel behavior on the other hand can also influence transportation and land-use policies (Arrow H).

Development patterns also provide opportunities and barriers for policy implementation (Arrow B reverse). High residential and employment densities, and mixed-use land-use patterns for example, make transit and transit investments economical, which would not be financially viable in low density suburban areas.

Socioeconomics can also influence the settlement structure, as wealthier households seem to have a tendency to live in larger houses in lower density suburban neighborhoods in the U.S. (Arrow D). Additionally, socioeconomics and demographics directly influence travel behavior (Arrow E). The young, the elderly, women, the poor, and the unemployed tend to travel less and make fewer trips by automobile. Socioeconomics and demographics of course also influence transportation and land-use policies directly (Arrow G).

Culture influences travel behavior and land use (Arrows F). It is argued that American culture, resulting from an individualistic lifestyle and distaste for taxation and government involvement, is connected to car use and more spread out settlement patterns. For Germany, on the other hand, it is argued that a greater acceptance of government involvement makes state restrictions on property development rights and higher gas taxes feasible.

To explain how the four groups of explanatory factors potentially contribute to differences in travel behavior in Germany and the U.S. the following section will describe how the explanatory factors are linked to travel behavior and how they could account for similarities and differences between the two countries.

3.4.2.1 Socioeconomic and Demographic Factors

The Socioeconomic variables used in most analyses were income and automobile ownership. Depending on the unit of analysis income was measured as gross domestic (nationally) or gross regional (regionally) product, household or personal income. In general, the higher the GDP of a country was or the more a family/individual earned, the higher the level of automobile ownership and use was.

Income was highly correlated with automobile ownership; the higher the income was, the more the higher automobile ownership levels were. The theory behind this empirical connection has been rarely laid out, but in economic terms it could be seen as an income effect or a substitution effect. The higher the income the more likely individuals are to substitute cars for trains, bikes or walking. The higher the income, the higher the level of car ownership, the more miles traveled and the more trips by automobile.

While income and auto ownership have been seen as good predictors for mode choice and travel distance internationally, they might have lost their predictive power for work trips within industrialized countries. Most households in these countries own cars and the growth in travel has been attributed to increased shopping and leisure activities (Kunert & Lipps, 2005). Other important socioeconomic factors included educational level and employment status.

<u>Demographic</u> variables included in most studies were the household structure (e.g. single, two adults, or family with children), having a driver's license, as well as the gender and age of household members. Holding other factors constant, it has been empirically shown, that the very young, the elderly, the unlicensed, the unemployed and women made fewer and shorter trips than working males individuals between 18 and 65 with jobs.

Socioeconomic and demographic variables can be easily quantified and collected through surveys and might be helpful in explaining similarities and differences between Germany and the U.S. (see Table 3.5). Differences in travel behavior between Germany and the U.S. may be attributed to comparatively lower incomes, higher unemployment rates, lower female workforce participation, a lower share of population with driver's license, and lower automobile ownership levels in Germany. These factors all could help explain shorter travel distances and fewer trips and miles traveled by car in Germany.

Table 3.5 Socioeconomic and Demographic Variables as Explanatory Factors for Travel Behavior - Anticipated Effects

Variable	**Anticipated Effect in Both Countries**	**Differences Between the Countries**
Age	Young and elderly drive less and make fewer trips than 18 - 65 year old.	Larger share of elderly in Germany; earlier driving age in U.S.
Gender	Men travel and drive more than women.	More traditional gender roles and less female travel in Germany
Driver's License	Driver´s License holders drive more and make longer trips.	Higher percent of license holders in U.S. (esp. among elderly and 16-18 year olds)
Income	Higher incomes lead to more driving and longer trips.	Higher average income in the U.S.
Car Ownership	Higher car ownership leads to more car travel and longer trips.	Higher average car ownership rate in the U.S.
Employment Status	Employed travel and drive more than unemployed.	Higher levels of unemployment in Germany
HH Structure	Members of larger HH make fewer trips, as some trips are shared mong HH members (e.g. errands).	Higher share of HH with children in the U.S.

3.4.2.2 Spatial Development Patterns, Land Use, and Urban Form

Urban form, spatial development patterns, and land use influence travel speed, costs, quality, and offer opportunities and barriers to all modes of transportation. Low density, spread- out development makes transit supply uneconomical, as there are not enough riders living within a range to support a financially viable transit service. Walking and cycling are not easily possible, due to relatively long distances between origins and destinations of trips, and often lack bicycle and pedestrian infrastructure (e.g. walkways and bike lanes). These settlements foster car travel, which easily covers longer distance at higher speeds.

Higher residential and employment densities provide for shorter distances between trip origins and destinations and therefore potentially more opportunities for walking and cycling. Dense developments also display a higher potential for traffic congestion, thus making car travel slower and less attractive. Additionally, higher densities make the provision of public transportation economical (TRB 2001). Public transportation needs a certain level of density to attract enough riders to make it financially viable. Residential density is also very frequently used as a proxy for other variables not readily available for multivariate analysis, such as quality of pedestrian facilities, ease of walking and cycling and limitations for car use (e.g. parking availability). It is assumed that denser areas provide better pedestrian and cycling facilities and an overall more conducive environment for walking and cycling. Studies have shown that relatively self-contained, dense, mixed-use urban areas display higher levels of bike and walk trips, as well as transit use.

Spatial context and travel behavior have a mutual influence on each other. A definite causal relationship flowing from land use to transportation cannot be clearly determined as the automobile allows for low-density settlements, but at the same time these kinds of settlements then require the availability of a car for daily activities. Furthermore, there might be a self-selection effect in neighborhood choice. Individuals, who want to cycle, walk, or use transit more often tend to move in denser and mixed use neighborhoods. Overall, studies have found that spatial development and land use variables account for less variability in travel behavior than socioeconomic and demographic variables (Axhausen, 2003).

Differences and similarities in travel behavior in Germany and the U.S. can potentially be explained by diverging spatial development patterns and land uses (see Table 3.6). In both countries higher residential and employment densities, combined with mixed uses lead to shorter trip distances. The number of walk and bike trips, as well as their modal shares, increases with density and mix of land uses. There might be a "*density threshold value*", which marks the starting point for changes in travel behavior. Dunphy and Fisher (1996) and Levinson and Kumar (1997) found this to be 7,500 people per square mile for the U.S. Below this threshold, changes in density only led to marginal changes in travel behavior. Pisarski and colleagues (2006) show this value to be even higher for the worktrip (about 10,000 people per square mile). Among others, this might be related to access to transit service, which only becomes feasible in more densely populated areas.

Differences between Germany and the U.S. in travel behavior might be attributed to higher density and more mixed-use development as well. Generally, better accessibility to non-automobile transportation in Germany can account for higher levels of walking, cycling and transit use. American cities are less dense (employment and residential density) and have more segmented land uses than German cities, providing for longer trip distances and increased automobile travel. Germany's cities and even communities in rural areas are much denser than their U.S. counterparts.

The higher share of Germans living in dense areas may help explain differences in travel behavior between the countries. The effect of density within the country is somewhat less clear. Giuliano (2003, 2004, 2005, and 2006) found in her comparison of the U.S. and the UK that density variability within the U.S. played a larger role in explaining differences in travel compared to the UK. Her explanation is that English settlements are denser overall and that the effect of density is therefore less pronounced. It is expected that this may also be the case with Germany and the U.S.

For both countries the size of metropolitan areas is expected to influence travel behavior, with larger metropolitan areas showing longer trips. The larger a metropolitan area is the more potential trip destinations are in reach for the trip maker. Smaller metropolitan areas provide fewer potential destinations (Levinson & Kumar, 1997). Generally, German metropolitan areas are smaller than U.S. metropolitan areas (with the notable exception of the Rhein-Ruhr and the Rhein-Main areas).

Additionally, it is expected that suburban areas display longer trips than urban areas. The somewhat generic definition of "*suburb*" hides considerable variation in density. Therefore it is expected that denser suburbs, potentially closer to the city center display shorter trip distances and less car travel than more distant low density suburbs.

Table 3.6 Spatial Development and Urban Form Variables as Explanatory Factors for Travel Behavior in Germany and the U.S.

Variable	**Anticipated Effect in both Countries**	**Differences between the Countries**
Residential Density	Higher density leads to shorter trips and less car use.	Overall higher densities in Germany. Less variability of density in Germany.
Workplace Density	Higher density leads to shorter trips and less car use.	Overall higher density in Germany. Less variability of density in Germany.
Mix of Land Uses	Mix of land uses leads to shorter trips and less car use, more transit and non-motorized travel.	Overall greater mix of land uses in Germany. Less variability in Germany.
Size of Metro Area	The larger the metro area, the longer the trips.	Larger metro areas in the U.S.
Urban or Rural Location	More and longer car trips in rural areas.	More contained rural settlements in Germany.
Urban or Suburban	More and longer car trips in suburbs.	Higher share of suburban population in U.S.

3.4.2.3 Policies Affecting Transportation Demand, Supply and Land Use

Transportation and land-use policies shape transportation supply and demand. Policies at all levels of government influence the costs, feasibility, and convenience of transportation modes.

Demand Side Policies

Demand side policies include: (1) pricing; (2) transportation demand management (including restraints on automobile use); and (3) regulation of automobile performance (Cervero, 1998).

Higher costs of operating and owning an automobile lead to less automobile travel. Major costs for automobile travel include gasoline and sales taxes, automobile registration fees, and insurance costs.

Traditionally, the gas tax has been higher in Germany than in the U.S. All else equal, higher costs per automobile kilometer (mile) driven leads to less automobile travel. This can either be the result of overall less travel during a given period, or a higher percentage of trips made by transit, walking, or cycling. Annual vehicle registration fees and vehicle purchase taxes[24] are higher in Germany than the U.S. Higher costs for purchasing and owning an automobile together lead to lower automobile ownership and use. In the U.S. some states and metropolitan areas charge road tolls for their major highways or user fees for tunnels and bridges. In Germany there is only one example for user charges for tunnels, which was opened during the 1990s. Even though U.S. states and metropolitan areas have a longer history of road user charges, these are only levied on comparatively few roads and tunnels.

[24] Sales taxes on automobiles are about 10 percent higher in Germany than in the US.

The costs of public transportation have a similar effect as the cost of automobile use – the higher the cost per mile traveled the fewer public transportation passenger miles of travel. The German federal and state governments subsidize transit tickets for the elderly, the poor, and school children to make transit more attractive. Additionally, monthly and annual tickets often provide steep discounts for regular users. Many U.S. transit systems also provide reduced transit fares for certain groups. In fact, subsidies per passenger for the operation of U.S. transit systems were on average higher than subsidies in Europe in the late 1990s (TRB, 2001). This is mainly due to lower efficiency in the U.S. transit system. The main difference between Germany and the U.S. might not be found in pricing for transit, but in transit supply, frequency and quality of transit service, as well as its integration with other modes (see the section on supply below).

Parking management is one of the most powerful transportation demand management techniques. On the local level many cities in Germany try to limit car travel by reducing the number of parking spots and increasing the prices for car parking in urban areas. Free car parking at the destination of most trips in the U.S. is a significant subsidy for automobile use (Manville & Shoup, 2004; Shoup, 1999, 2005). In contrast to most German zoning codes, U.S. municipalities often require minimum parking spaces with new developments. This leads to ample supply of parking spaces.

Most German cities have implemented car-free zones in downtown areas. These areas are off-limits for automobile travel and solely used by pedestrians, cyclists, and sometimes public transportation vehicles. No U.S. city has a network of connected pedestrianized downtown streets, but cities such as Madison, WI or Minneapolis, MN have one single pedestrian street in their downtowns.

Most German cities have traffic-calmed their residential areas. Traffic calming requires cars to travel at 19 mph. Slower speeds make car travel less attractive. Regulatory management techniques such as requiring seatbelt use, setting standards for the quality of gasoline, and pollution standards for vehicle exhausts exist in both countries.

Supply Side Policies

Supply of transportation can be grouped into (1) infrastructure supply, (2) "*infostructure*" *(sic!)* level, and (3) Level of Service (LoS) (Quinet & Vickermann, 2004). Infrastructure refers to the physical transportation system, such as roads, rails or sidewalks. "*Infostructure*" provides information so that the existing transportation infrastructure can be used most efficiently. This includes Intelligent Transportation Systems (ITS) or Geographic Positioning Systems (GPS) guiding automobiles through cities and around congested areas. Level of Service (LoS) relates to price, frequency and quality of the transportation service purchased by the customer.

As already mentioned, infrastructure, "*infostructure*", and LoS of public transportation in German cities is very different from transit services found in most U.S. cities. Many U.S. cities do not have rail transit or do not have viable transit service outside of peak commuting hours. Subsidies for transit, as well as the integration of transit planning and management on the regional level are two causes for these differences. German transit agencies were publicly subsidized continuously throughout the second half of the 20th century, while U.S. transit systems only received government attention during and after the 1960s. In contrast to most U.S. transit systems, Germany local transit authorities cooperate within a regional transit authority (Verkehrsverbund). The customer can use all transit services in the region with one ticket.

Additionally, integration of public transportation with other transportation modes is an important aspect of mode choice. Bike and automobile parking at transit stops, integrated fare structures, the ability to take a bike on transit are examples of integration policies.

Transportation infrastructure supply is closely related to the use of transportation modes and distance traveled. The vast increases in road supply in the U.S. and Germany contributed to fast, reliable and convenient car travel. Germany and the U.S. have the two largest and most densely knit highway systems in the world (ADAC, 2006). The destruction of trolley tracks in most U.S. and some West German cities ended the streetcar era. More recently, the U.S. federal government is funding new trolley systems through its so-called "*New Starts*" program.

There is still no conclusive evidence over the influence of bike paths and lanes on the level of cycling, but it seems logical that the existence of safe and convenient facilities for cycling, everything else equal, encourages potential bike trips. Currently, without separate facilities, the physical environment for walking and cycling is often dangerous in the U.S. It is shown that cyclists are twice as likely and pedestrians are three times as likely to be killed in traffic in the U.S. as in Germany (Pucher and Dijkstra, 2003).

Land-use policies

Policies towards land use have an important impact on travel behavior. Land-use planning in Germany is more regulated and stricter than in the U.S., integrating different levels of government. Generally speaking, German regional and state governments have to review any local development not adjacent to existing settlements. Land-use planning in the U.S. is mainly subject to local regulation and not influenced by state or regional plans. Building restrictions outside of already developed areas rarely exist.

Additionally, there are no formal links between transportation and land-use planning on all levels of government in the U.S. as in Germany, making it more difficult to coordinate the development of transportation infrastructure and settlement structure. Stricter rules on land development and more coordination of land use and transportation are expected to result in more compact settlements with higher densities in Germany. Higher densities, and potentially more mixed use can account for shorter trips and more non-motorized travel and transit use in Germany.

Table 3.7 Land Use and Transportation Policies as Explanatory Factors for Travel Behavior in Germany and the U.S.

Variable Transport Policies	**Anticipated Effect in both Countries**	**Differences between the Countries**
Gas Tax	Higher operating costs lead to less car travel.	Higher gas tax in Germany makes car travel more expensive than in the U.S.
Car Purchase Tax	Higher purchase tax lead to lower automobile ownership levels.	Overall higher tax in Germany (about twice as high).
Vehicle Registration Cost	Higher fixed cost lead to less car ownership.	Overall higher costs in Germany, especially for larger cars/trucks/SUVs.
Transit Supply and Level of Service	More transit supply and LoS lead to a higher percentage share of trips by transit.	More transit supply in Germany. Especially in smaller cities and rural areas.
Road Supply	More road supply leads to more car	More roads per capita in the U.S.
Bike Infrastructure	More and better bike infrastructure fosters cycling.	More bike infrastructure in Germany.
Parking Supply	More restrictions on parking reduces number of car trips.	Overall more limited parking supply in Germany vs. U.S.
Traffic Calming	Traffic calming foster non-car travel.	More extensive traffic calming in Germany.
Pedestrian Zones	Pedestrian zones foster short trips and more non-motorized trips.	More extensive pedestrian zones in Germany.
Bike and Pedestrian Safety	More safety for cyclists and pedestrians increases mode shares of non-motorized travel.	More dangerous walking and cycling conditions in the U.S.
Transit Subsidies	More subsidies increase transit ridership and level of service.	Historically more subsidies in Germany.
Land Use Policies		
Integration of Land Use and Transportation Planning	Better integration leads to shorter trips and less car travel.	More integration in Germany.
Cooperation of Local, Regional and State Governments	Cooperation of land use planning potentially limits sprawl and average travel distances.	More cooperation in Germany.

3.4.2.4 Cultural Differences and Similarities

Culture is often mentioned as an explanatory variable for differences in travel behavior. It is very difficult to measure and most multivariate studies treat it as a residual measure. Everything that is not explained by measured variables is attributed to a culture variable. On a more qualitative basis Gleesen and Low (2001) developed the theory of "*ecosocialization*", which is an indicator for cultural change in society as a whole. Other scholars describe weak political institutions and local self-government in the U.S. as part of a strong individualist culture formed during the settling of the country, which is absent in European countries. Cultural differences might also be related to different lifestyles. Differences in travel witnessed between the U.S. and Europe may be attributed to greater acceptance of government intervention[25], differences in corporate power over the transportation sector, and more concern about externalities of car use in Europe. For Germany these effects might be slightly less important since the country has a history of local self government and a strong car industry and lobby more similar to the U.S. than other European countries. All these factors, individual characteristics, spatial patterns, infrastructure supply, transport/land-use policies, and culture work together in explaining international differences in travel behavior.

[25] The U.S. population is very heterogeneous, so that some groups in society (e.g. newly arrived immigrants or other minorities) are more willing to follow government rules, while others do not.

4 Transportation Policies in Germany and the U.S.

4.1 Overview

All levels of government develop policies that influence the cost, accessibility, and convenience of different transportation modes. This chapter describes some of these policies, their purpose and how they compare in Germany and the U.S. The first two sections (4.2 and 4.3) investigate trends in automobile and public transportation costs, and rationales for differences in the two countries. For example, gasoline taxes are much lower in the U.S. than in Germany, resulting in lower operating costs per kilometer driven. The average kilometer of travel on public transportation costs about the same in both countries and is higher than average automobile operating costs. In contrast to the U.S., most of the revenue from the gas tax is not earmarked for transportation investments in Germany and therefore serves as a financing tool for all kinds of government programs.

The third section compares household expenditures on transportation. Although gasoline is much cheaper in the U.S., households in America spend a higher share of their budgets on transportation. This is most likely a result of higher automobile ownership levels and the fact that, Americans drive twice as many kilometers by automobile per resident per year than Germans. The subsequent section (4.5) describes government supply-side policies supporting road and rail transportation. All levels of government fund and subsidize transportation in both Germany and the U.S., although subsidies for public transportation have a longer history and are traditionally higher in Germany. Supply of transportation infrastructure may be related to the consumption of transportation. Therefore this section also includes trends in demand by mode. Finally, section 4.6 describes miscellaneous policies affecting transportation demand and supply, such as regional coordination of transit services and car-free zones.

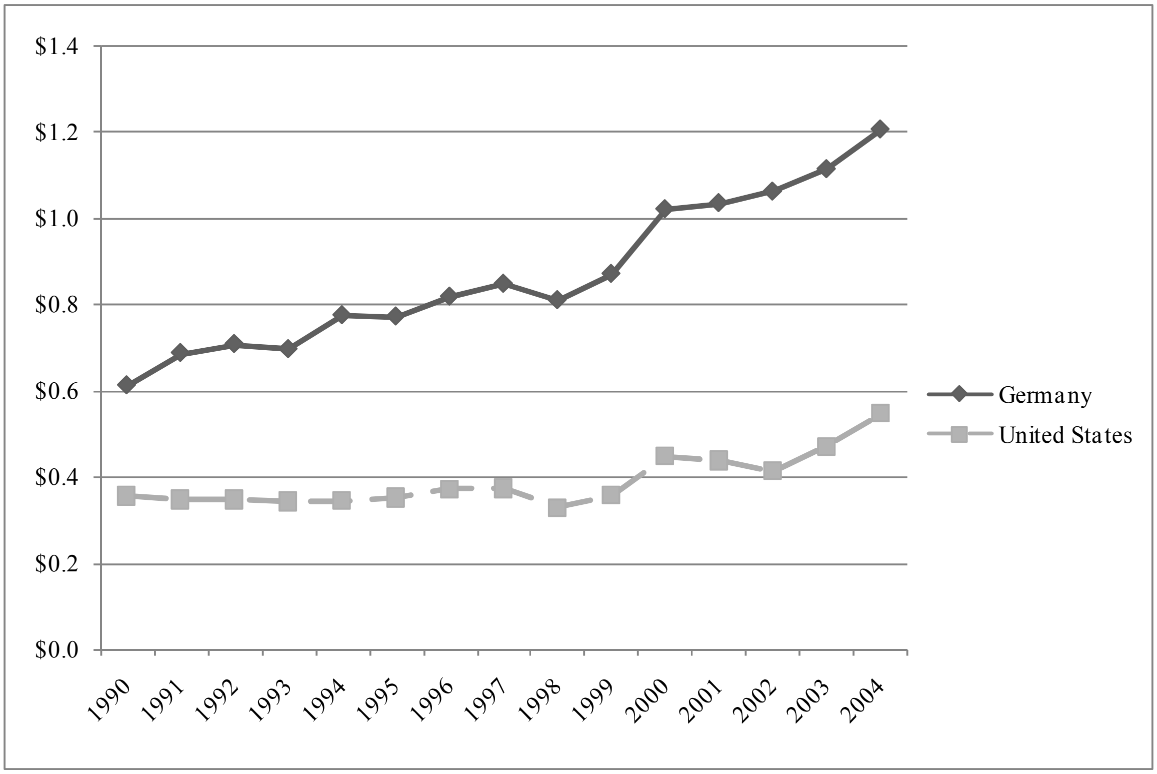
4.2 Costs of Automobile Ownership and Use

Fixed costs of automobile ownership include annual vehicle registration fees, insurance premiums, depreciation of the value of the automobile, and taxes levied on purchase and ownership. Variable or operating automobile costs include the price of gasoline, gasoline taxes, highway tolls, periodic maintenance, and prices of and taxes on motor oils. This section starts with a discussion of these costs by examining in detail taxes on gasoline and diesel and proceeds to a discussion of the average cost per kilometer driven of owning and operating an automobile.

4.2.1 Gasoline Prices and Taxes

In 2004 the price of a liter of regular unleaded gasoline was U.S. $1.2 in Germany, compared to $0.6 in the U.S. (about $4.5 and $2.1 per gallon respectively (adjusted for ppp)).

Exhibit 4.1 Unleaded Gasoline (Petrol) Prices per Liter in the U.S. and Germany, 1990 - 2004 (in U.S. dollars, using PPP conversion)



Source: (IEA, 2005)

Exhibit 4.1 shows the trend of the price of a liter of gasoline in both countries from 1990 to 2004. The average price of gasoline was more than twice as high in Germany as in the U.S. during this time period. Since the petroleum market is a global one, most countries face similar wholesale gasoline prices. As a result, this difference in price at the pump is primarily a function of divergent gasoline taxes and not differences in the price of petroleum or gasoline.

From 1960 to 2005, between 60 and 70 percent of the gasoline price at the pump in Germany consisted of gas[26] and sales taxes. The remaining 30 to 40 percent represented the market price of crude oil and profits for oil companies (ARAL, 2007;

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[26] The gas tax is referred to as mineral oil tax in Germany. These two terms will therefore be used interchangably.

BMF, 2005). In the U.S. the ratio was just the reverse; only 30 to 40 percent of the gas price was made up of taxes, while 60 to 70 percent were either profits or covered costs of oil companies and distributors (BTS, 2007; Puentes, 2003). This huge difference is due to Germany's taxes on gasoline, which are approximately eight times higher than the U.S. average tax on gas. In 2004, the tax per liter of gasoline in Germany was $ 0.8 compared to $ 0.1 in the U.S. (adjusted for purchasing power parities (IEA, 2005)).

There is no local or state tax on gasoline in Germany, thus making the breakdown of revenue streams fairly straightforward. The share of taxes in the gasoline price in Germany consists of the mineral oil (gas) tax and a 16 percent sales tax[27] levied on all sales including gasoline, as well as a small fee dedicated to the national energy reserves (BMF, 2005).

In the U.S., taxes on gasoline are levied by local, state and federal governments (see Table 4.1). In 2003, the federal government imposed a five cent tax on every liter sold (18.4 cents per gallon). Table 4.1 shows that in 2003 state taxes on gasoline varied widely, from as low as two cents per liter in Georgia to eight cents in Rhode Island. Generally, state gas taxes were slightly more than five cents per liter. State gasoline taxes may vary annually based on the cost of fuel, and depending on the state statutes establishing the tax. States can lower their own gas taxes as a relief valve in the event that whole sale fuel prices precipitously increase. Local and state governments charge sales taxes on top of the price of gasoline. In 2003, the average shares of gas taxes in the price of gasoline were 43 percent federal, 50 percent state and seven percent local (Puentes, 2003).

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[27] The sales tax increased to 19 percent in 2007.

Table 4.1 Summary Statistics of Federal and State Gasoline Taxes in the U.S. 2003, (in U.S .cents)

FEDERAL				
		Per Gallon	*Per Liter*	
Gasoline		*18.4*	*4.9*	
Diesel		*24.4*	*6.5*	
STATES				
		Per Gallon	*Per Liter*	*State*
Gasoline	*Mean*	*20.5*	*5.4*	
	Median	*20.3*	*5.4*	
	Lowest	*7.5*	*2.0*	*Georgia*
	Highest	*30.0*	*7.9*	*Rhode Island*
Diesel	*Mean*	*21.0*	*5.5*	
	Median	*21.0*	*5.6*	
	Lowest	*7.5*	*2.0*	*Georgia*
	Highest	*30.5*	*8.1*	*Pennsylvania*

Source: (FHWA, 2006)

4.2.2 History of the Gasoline Tax

The histories of the gas tax and the use of its revenue are quite different in Germany and the U.S., which in large part helps to explain the vastly different levels of taxation today. In the U.S. the gasoline tax was earmarked for transportation expenditures in many states and at the federal level[28]. In Germany the gas tax (generally speaking) goes towards the general fund, thus serving as an important financing tool for many different government projects.

In the U.S., Oregon was the first state to tax gasoline in 1919 (Wachs, 2003). By 1929, all U.S. states had introduced some form of gasoline tax, mainly to help finance their road building efforts (Puentes, 2003). While most road infrastructure projects were originally funded from general government revenues, some states earmarked their gasoline tax revenues for road construction projects only (Weiner, 1996). Many states

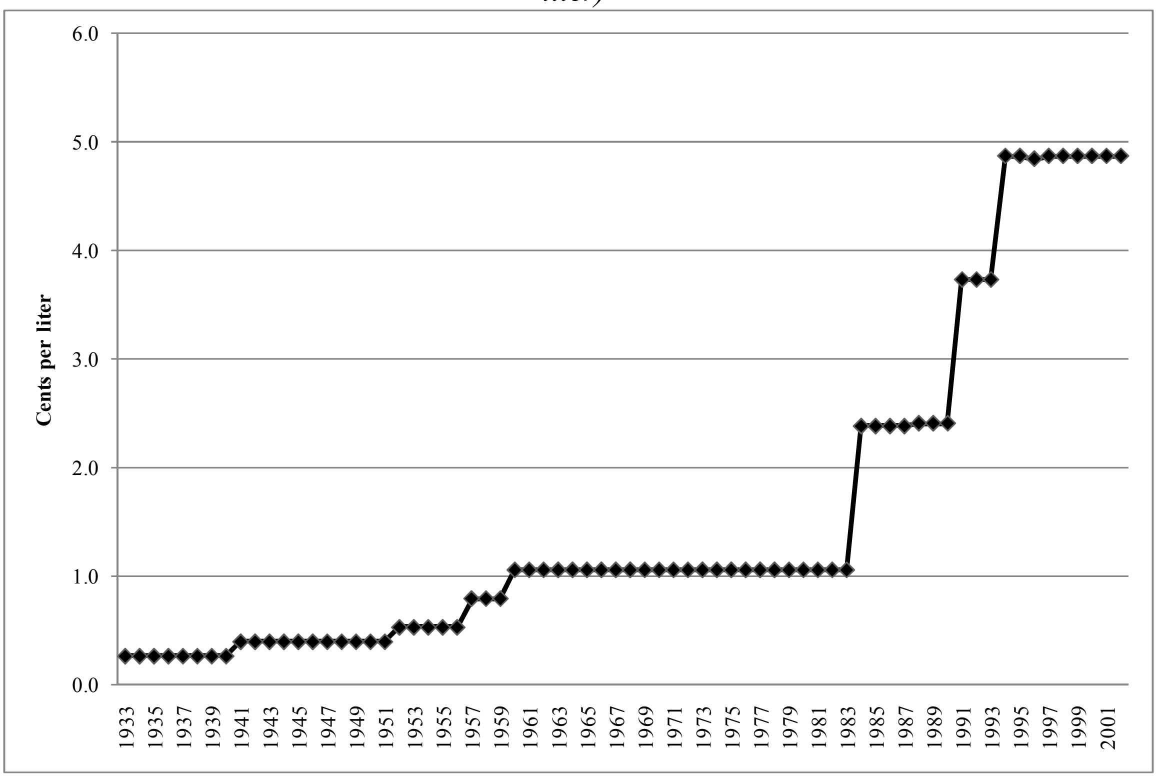
[28] Nonetheless many states, such as New Jersey, diverted highway trust fund moneys towards non-transportation related projects.

followed suit and today about 30 states have their gasoline tax revenues earmarked for highway projects. For about 20 states this regulation is part of the state constitution (Puentes, 2003). Some U.S. states allow the use of a portion of gasoline tax revenues for the general fund or for public transportation (for details see (Puentes, 2003)).

In 1932, the U.S. federal government levied its first gasoline tax at the rate of one cent per gallon (0.3 U.S. cent per liter). The tax was intended to provide a temporary relief during the federal government's financial crisis following the stock market crash of 1929. The revenue from the new tax went into the general fund and could therefore be used for general government spending. The Federal Highway Act and the Highway Revenue Act of 1956 established that earmarked gasoline tax revenues should go exclusively to the Highway Trust Fund, which was used to finance highway construction (Dunn, 1981; Puentes, 2003; Weiner, 1992; Yago, 1984). The Federal Highway Trust Fund fuelled highway infrastructure construction all over the country. Among other projects, it helped finance the interstate highway system—connecting all states and major cities of the U.S.—with a 90 percent federal and 10 percent local funding share(Weiner, 1996). Due to the design and maintenance of the Highway Trust Fund, gasoline and motor oil taxes did not need to be raised for a long time. More highways and better accessibility by automobile, combined with increasing incomes led to more vehicle kilometers traveled (VKT). More VKT meant increased gasoline tax receipts, which were used to fund more highway construction, which in turn led to more driving and higher gross gasoline tax receipts.

Consequently, the federal gas tax remained at four cents per gallon (1.1 U.S. cents per liter) from 1960[29] to 1982. In 1982, the Surface Transportation Act increased the gas tax by another five cents and dedicated one cent of this increase for public transportation capital projects. In 2003, $ 0.15 of the federal gas tax was earmarked for highways, while $ 0.03 went towards transit projects (Puentes, 2003).

Exhibit 4.2 Trend of Federal Gas Tax in the U.S., 1933-2001 (in current U.S. cents per liter)



Source: (BTS, 2007)

In Germany the gas tax and the dedicated use of its revenue took a different path. As noted previously, there is only a federal tax on gasoline. In 1879 the German Reich, the predecessor to today's Federal Republic, introduced the first tax on petroleum (Petroleumszoll). In 1930, the mineral oil tax was introduced for gasoline fuels. In 1939,

[29] The federal gas tax was increased from one cent to four cents in 1960.

it was also levied on diesel fuels and after WWII it was extended to petrochemical products and heating oil. At the end of WWII, the mineral oil tax served as a useful instrument for funding reconstruction in Germany (BMF, 2005).

Generally, taxes cannot be earmarked in Germany, as the German budgeting law[30] stipulates that all taxes must go into the general fund.[31] This principle assures that all proposed government investments must compete for resources from the general fund, with the intention that only the highest quality and most efficient investments will be made. As is the case with all other taxes, most of the gasoline tax revenue in Germany is not earmarked for transportation investments. This does not, however, preclude funds being used for transportation projects, and in fact gas tax revenue has been used for transportation purposes, such as improvements on federal highways.

Since 1955, however, some increases of the gas tax have been temporarily earmarked for highway construction (mainly before 1971). Additionally, the German Municipal Transportation Funding Law of 1967 (GVFG or Gemeindeverkehrsfinanzierunggesetz) requires the federal government to use a share of the gas tax to fund local transportation improvement projects (including road and public transport) (Bundesregierung, 1999). The amount of taxes earmarked for the GVFG and their use changed multiple times over the last 40 years. Some gas tax increases were specifically earmarked for public transportation (e.g. the tax increases in 1967 and 1972). Earmarking of gas taxes is an exceptional practice and its legitimacy was questioned, as funds usually must be dispensed through the general fund on a competitive basis for different projects (Bundesregierung, 1999).

[30] Paragraph 7
[31] Non-Affektationsprinzip

Since 1971 gas tax revenue has been used for funding all transportation infrastructure and more recently even for financing social security (Paellmann, 2000)[32] Between 1951 and 2004, the gas tax was changed 22 times, raising the tax rate from about two € cents per liter (11 U.S. cents per gallon[33]) in 1951 to 65 € cents per liter (307 U.S. cents per gallon[34]) in 2004 (see Exhibit 4.3). The tax on leaded gasoline in 2004 was 72 € cents per liter (355 U.S. cents per gallon[35]) (MWV, 2007). In 2007, diesel fuel was taxed at a rate approximately 25 percent lower than gasoline.

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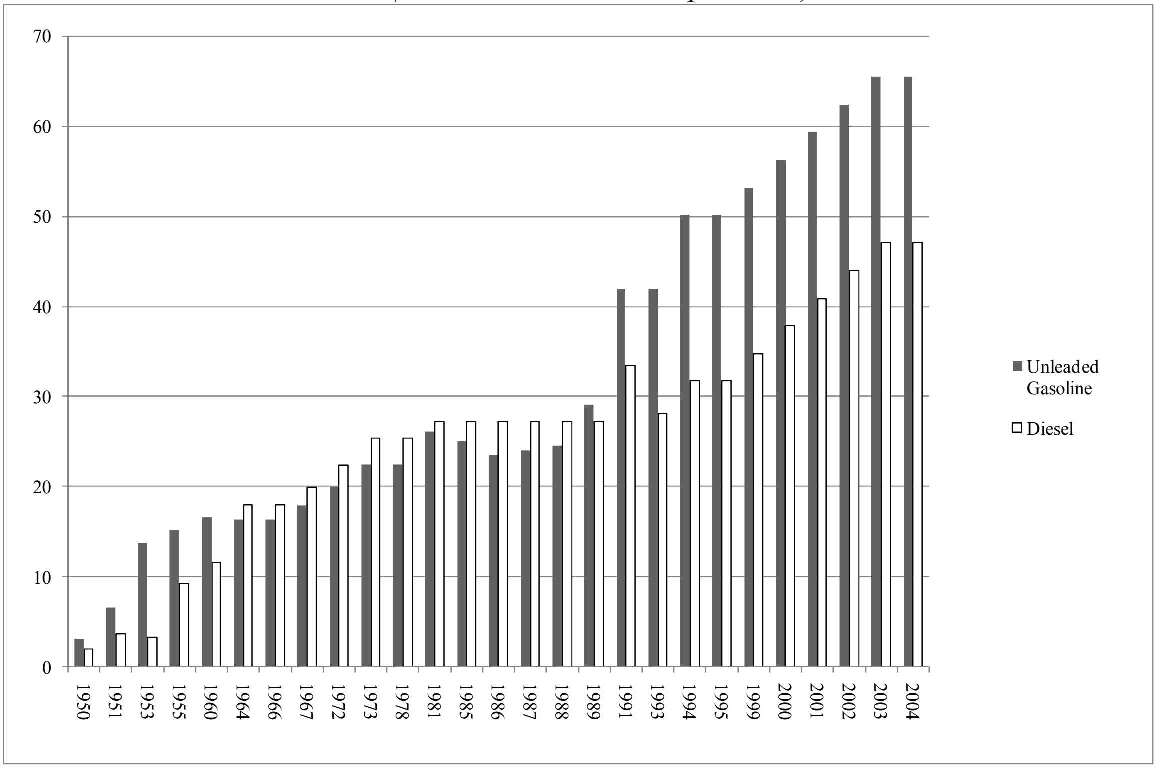
[32] „Eine Zweckbindung der Mineraloelsteuer zur Finanzierung der Bundesverkehrswege lässt sich bis 1971 verfolgen. Im Jahre 1973 erfolgte letztmals eine Erhoehung der Mineraloelsteuer um five Pf. pro Liter mit einer Zweckbindung zur Finanzierung der Straßen. Seit 1971 wurden die Einnahmen durch die Mineraloelsteuer zunehmend zur Finanzierung aller Verkehrswege herangezogen und tragen heute wesentlich zur Finanzierung anderer Bundesaufgaben, wie seit 1999 der Rentenkassen, bei.“ *„Earmarking of mineral oil tax revenues first occured in 1971. The last earmarked tax increase occured in 1973, when the additional tax revenue of five Pfennigs per liter was dedicated to finanzing roads. Since 1971 the mineral oil tax reveneu was increasingly used for financing all modes of transportation and are a substantial funding soruce for other Federal programs, such as social security.“*

[33] This is 11 € cents or 14 U.S. cents at current April 2007 exchange rate.

[34] This is 246 € cents per gallon or 307 U.S. cents per gallon at current April 2007 exchange rate.

[35] This is 284 € cents per gallon or 355 U.S. cents per gallon at current April 2007 exchange rate.

*Exhibit 4.3 Trend of Taxes on Unleaded Gasoline and Diesel Fuels in Germany, 1950 – 2004 (In Current Euro cents per Liter)**



**Note: Tax for gasoline is for leaded gasoline until 1981 and unleaded thereafter. Data for 1950 - 1990 is for West Germany only.*
Source: (MWV, 2007)

From 1999 to 2004 the gas tax increased by $0.04 per liter every year to a total of $0.20 (about $ 0.75 per gallon). These tax increases were part of a larger taxation scheme called "*environmental tax reform*" implemented by the Social Democratic and Green Party federal government in power during that period. The tax revenue collected under the program was used to lower social security taxes, thus potentially offsetting the negative income effect of the gas tax increase[36]. According to the German Ministry of the Environment (UBA, 2005), about 91 percent of the tax revenue collected goes towards the reduction of social security taxes.

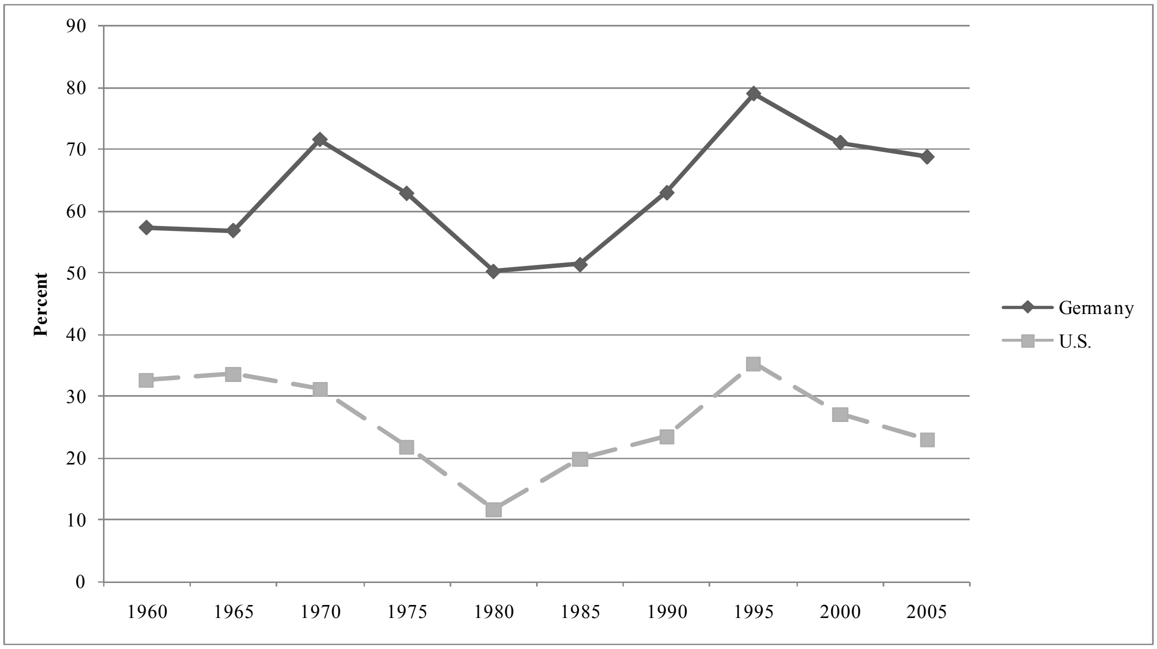
[36] The tax was critizised for its regressive effect on lower income strata of society.

Compared to the U.S., where the gasoline tax is used almost exclusively for funding transportation and especially for highway purposes, German policy makers have always viewed the gas tax as a welcome financing addition to the general fund. The two large gas tax increases at the beginning of the 1990s, for example, were intended to help finance German reunification and the restructuring of German railways.[37] Currently, the mineral oil tax is the most important excise tax in Germany and the single largest tax solely dedicated for the federal government (Bundessteuer). Taxes in Germany can be divided into four categories. The first three are federal, state and local taxes, for which tax revenue goes exclusively to one of the levels of government. Additionally, there are "*shared*" taxes, for which the tax revenue is shared among federal, state or local governments (e.g. the income tax). In 2006, total tax revenue for all levels of government was $634 billion (€488 billion), of which $437 billion (€336 billion) were tax revenue shared among different levels of government and $109 billion (€84 billion) were exclusively federal taxes. Of the federal taxes, close to 50 percent ($53 billion (€41 billion)) were revenues from the mineral oil tax. In 2006/2007, close to 90 percent of mineral oil tax revenues came from fuels (BMF, 2006b, 2007).

The share of taxes in the price of a liter of gasoline has increased in Germany from 60 percent in 1960 to 70 percent in 2005. The U.S. saw a reverse trend where the percentage share of taxes decreased from slightly above 30 percent in 1960 to slightly above 20 percent in 2005 (see Exhibit 4.4). Obviously, the slopes of the two curves change almost simultaneously, as the share of taxes also depends also on the world market price of crude oil. In times of high crude oil prices, the share of taxes is lower in both countries.

[37] DS14/3682, see: http://dip.bundestag.de/btd/14/036/1403682.pdf (German Parliamant, 2000)

Exhibit 4.4 Trend in percentage share of taxes in the price of a liter of gasoline in Germany and the U.S., 1960-2005



Sources: (ARAL, 2007; BTS, 2007)

4.2.3 Costs of Driving an Automobile: Fuel Efficiency Matters

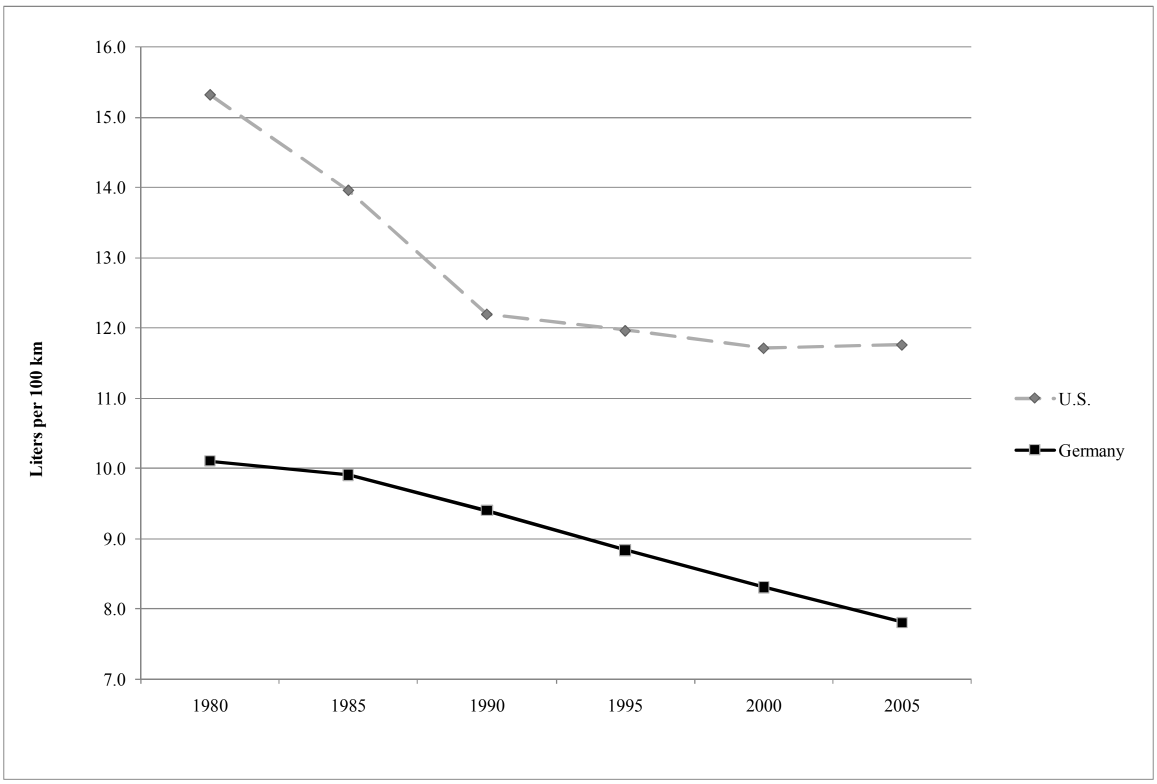
Higher taxes on gasoline can partially explain why fewer vehicles kilometers are driven per year in Germany than the U.S. The actual cost per kilometer paid by consumers, however, is mitigated by the fuel efficiency of the vehicle fleet. Exhibits 4.3a and 4.3b show that since 1980, the fuel economy of German vehicles has been higher than in the U.S., therefore potentially offsetting the effect of higher gas prices on kilometers of car travel. In fact, the higher fuel efficiency of the vehicle fleet might be a result of higher fuel prices, as other things being equal, higher gas prices would tend to increase the demand for more fuel efficient vehicles.

Huge improvements were made in fuel efficiency in the U.S. during the 1980s as a result of the federal Corporate Average Fuel Economy (CAFE) Standards. In direct response to the OPEC oil embargos of 1974 and 1979, the CAFE standards required car manufacturers to achieve sales-weighted fuel economy standards. The average fuel efficiency of all vehicles sold had to remain above a certain standard or the manufacturer had to pay a penalty (Greene, 2004). The CAFE standards increased in increments beginning in 1978 and reached their maximum of 27.5 miles per gallon (8.5 liters per 100 km) for passenger cars in 1985. The standard has not changed since then, thus leading to a decline in the rate of improvements in fuel efficiency of the passenger car fleet. Additionally, the CAFE standards were less stringent for SUVs, light trucks, or other heavy-weight vehicles, reaching 20.7 miles per gallon in 1996, 21 mpg in 2005, and 21.6 mpg in 2006 (11.4, 11.2, and 10.9 liter per 100 km). SUVs and other light truck vehicles became very popular with consumers in the 1990s. A larger share of light trucks and SUVs in the total vehicle fleet meant that the overall fuel efficiency of all vehicles did not improve between 1990 and 2005. It is still about 20 miles per gallon, or slightly more than 11 liters per 100 kilometers traveled (Greene, 2004; Puentes, 2003). This means that the U.S. vehicle fleet in 2005 was less fuel efficient than the German fleet in 1980! The Energy Independence and Security Act, signed by the president in December 2007, set the target of increasing CAFE standards for new vehicles by 40 percent to 35 miles per gallon or 6.75 liters per 100km by 2020 (The White House, 2008).

The fuel economy of German vehicles has increased steadily since 1980 and was at 31 miles per gallon, or 7.8 liters per 100 kilometers traveled in 2005. Compared to the U.S., the German car and light truck fleet is 55 percent more fuel efficient. Germany does not have any government standards similar to the CAFE requirements. It appears that the relatively higher gas tax compared to the U.S. may steer consumer demand towards more fuel efficient vehicles. More and more cars in the

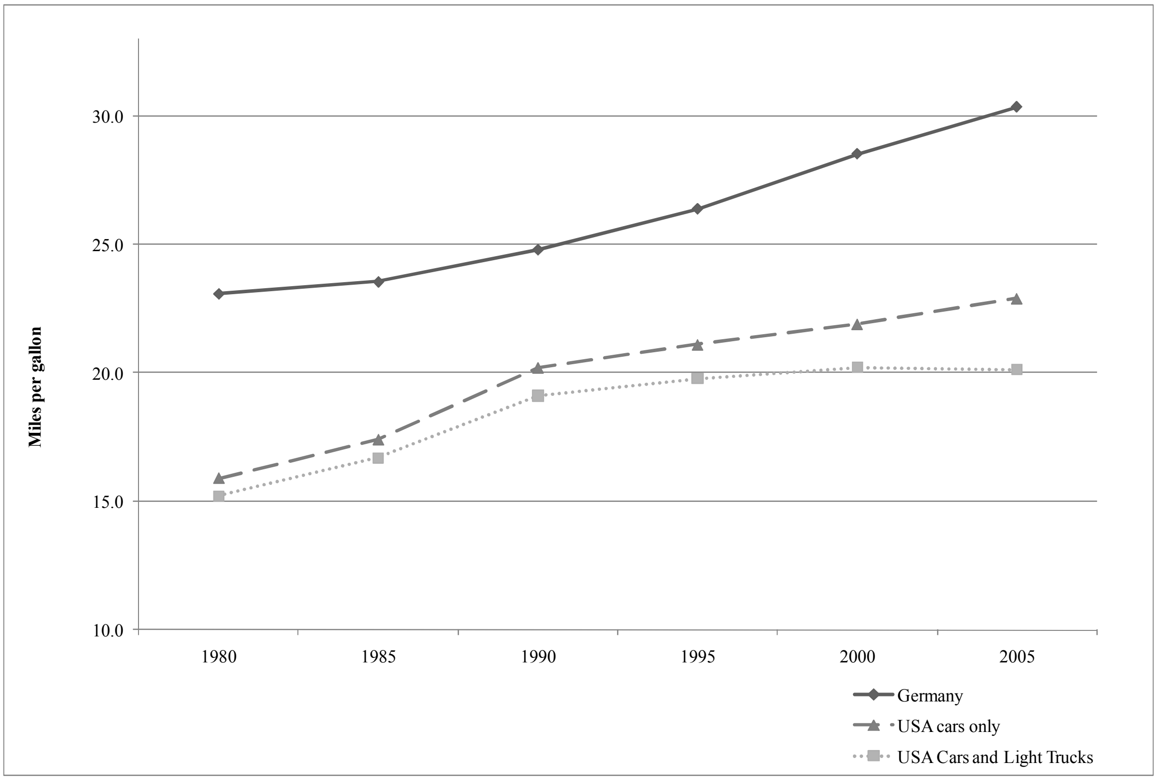
German vehicle fleet have diesel engines. This is related to higher fuel efficiency of diesel vehicles and lower gas taxes on diesel fuel (DIW, 2006). Additionally, some Germans avoid the high gas tax at home and refuel abroad, where gasoline is cheaper (UBA, 2005).

Exhibit 4.5 Average Fuel Economy of Registered Cars and Light Trucks in Germany and the U.S. (liters per 100 km, 1980-2005)



Sources: (BMVBS, 1991-2007; FHWA, 1990-2008)

Exhibit 4.6 Average Fuel Economy of Registered Cars and Light Trucks in Germany and the U.S. (miles per gallon, 1980-2005)



Source: (BMVBS, 1991-2007; FHWA, 1990-2008)

4.2.4 Costs of Buying and Owning and Automobile

Car purchases in Germany and the U.S. are subject to sales tax, which varies from state to state in the U.S.[38] and is set by the federal government in Germany. In 2007 the sales tax was 19 percent in Germany[39]. No U.S. state taxes automobile purchases as high as 19 percent, which means the purchase of a similar car is cheaper in the U.S. than in Germany. In both countries there has been no discussion of limiting car ownership via the sales tax. Other countries, such as Denmark, levy a special luxury tax on all car purchases. Germany and the U.S. apply the same sales tax to automobiles as to any other

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[38]As of 2005, state sales tax rates ranged from 0 percent - 7.25 percent (Federation of Tax Administrators, 2006).

[39] In both countries the sales tax is levied on used cars purchsaed from car dealers.

goods. This was different at the beginning of the 20th century in Germany, however. Car ownership levels were very low then and the German Reich levied luxury taxes on automobile purchases. This policy was discontinued in 1933 (Yago, 1984).

4.2.4.1 Registration Fees and Taxes

In 1906, the first motor vehicle registration tax was introduced in Germany and only levied on privately owned motor vehicles. Few private individuals owned vehicles then, and the registration tax was considered to be a luxury tax (DIW, 2005a). Since then, annual registration fees and the use of their revenues have changed several times. For example, in 1992 the tax base was expanded to also include commercially used vehicles. At the same time, 50 percent of the tax revenues were earmarked for road construction (DIW, 2005a).

Since the 1990s, registration taxes have been calculated based on European emission standards and engine size (BMF, 2006a). Older cars that emit more criteria pollutants were charged a higher tax than newer cars that comply with more recent emission standards. Cars with larger engines also pay a higher tax rate. It was the explicit goal of the government to promote less polluting and more energy efficient vehicles and to punish gas guzzling and polluting cars.

Diesel engines, which burn relatively dirtier diesel fuel, were also taxed at a higher rate. This higher tax rate was not related to environmental standards, however. Higher taxes on owning diesel cars were intended to compensate for lower diesel fuel prices. Additionally, a number of cars identified as especially environmentally friendly, based on their fuel economy and technology, were tax exempt for a certain period of time. From 1998 to 2004 less than 0.5 million cars qualified for a fuel efficiency tax break[40]; this was less than two percent of new cars sold in those seven years. Charging annual registration fees and providing tax exemptions based on tailpipe emissions and engine size have proven to be an incentive for the purchase of more environmentally friendly cars (BMF, 2006a).

Today vehicle registration fees in Germany vary widely among vehicle, exhaust, and engine types. In 2004, the annual registration fee for a small Volkswagen Golf with a gasoline engine in Germany[41] was €100 (U.S. $125), but the fee was €310 (U.S. $390) for the same car with diesel engine. In 2004, German taxes on smaller cars were relatively high compared to the other European countries. Conversely, charges on luxury vehicles were among the lowest in Europe (DIW, 2005a).

In 2000, the latest data available, U.S. annual vehicle registration fees and taxes ranged from as low as $20 to $200 depending on the state (TRB, 2001). The mechanisms for calculating the tax were not uniform across states (National Conference of State Legislatures, 1999). While some states calculated the fee based on the weight of the vehicle, others charged a flat fee per car, and California included a percentage of the current value of the automobile in its registration fee (National Conference of State Legislatures, 1999). Many states in the U.S. and all German states charged an additional initial registration fee for the registration of a new vehicle. FHWA (2001) reports that in 2001 registration fees for a typical automobile ranged from $8 in Arizona to close to $100 in Hawaii and Oklahoma.

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[40] For cars using less than five or three liters per 100 kilometers (47 and 79 miles per gallon).
[41] With 55 kilowatt engine and 1.4/2.0 cylinder capacity.

4.2.4.2 Insurance Premiums

While registration fees are difficult to capture because of their variability across states and car types, it is almost impossible to compare insurance premiums as they vary by state, insurance provider, extent of coverage, vehicle type, and the driver's safety record and other characteristics.

The National Association of Insurance Commissioners (2003) compares average insurance costs across U.S. states. In 2003, the annual insurance premium for liability, comprehensive and collision coverage for a regular vehicle in the U.S. was $940 dollars. The national average hides variability across states. The states with the lowest annual premiums were Iowa ($680), Wisconsin ($690), Idaho ($710), South Dakota ($730) and Maine ($730). The highest annual premiums were paid in New Jersey ($1,370), New York ($1,310), and the District of Columbia ($1,280), whose inhabitants paid almost twice the Iowa and Wisconsin rates.

Unfortunately there is no comprehensive overview of vehicle insurance premiums for Germany (since the deregulation of the industry), but the next section provides an overview of overall fixed costs for auto ownership, including insurance premiums.

4.2.5 Costs for Operating and Owning a Similar Automobile: An Example

The wide variability of costs of car ownership and use across states, cars, and individuals makes an international comparison difficult. This section provides a comparison of ownership and use costs of two relatively comparable cars in Germany and the U.S. The cars chosen were a Ford Taurus (U.S.) and Ford Mondeo (Germany). Both cars are manufactured by the same company (Ford), both are sedans built in 2002 with six cylinder engines and four doors, and data was available for both cars from the national Automobile Associations (AAAs). Table 4.2 below displays annual costs for ownership and operation of a Ford Taurus/Mondeo for three annual mileage categories (16,000, 24,000 and 32,000 kilometers) in Germany and the U.S.[42]

Table 4.2 Driving Costs for a Comparable Automobile in Germany and the U.S., 2002 (in U.S. Dollars, using PPP)

	U.S. 2002 Ford Taurus Deluxe SEL, 6 cylinder (3.0 liter), 4 door sedan				Germany 2002 Ford Mondeo 24 V Futura, 6 cylinder (2.5 liter), 4 door sedan			
Kilometers driven per year		**16,000**	**24,000**	**32,000**		**16,000**	**24,000**	**32,000**
Ownership Cost per Year	US $	5,700	5,700	6,625	US $	7,355	7,535	7,876
Depreciation	US $	*3,706*	*3,706*	*4,631*	US $	4,196	4,480	4,716
Other	US $	*1,994*	*1,994*	*1,994*	US $	3,159	3,055	3,160
Operating Costs per Year	US $	1,080	1,770	2,360	US $	2,600	3,719	4,824
Gas and Oil	US $	*590*	*885*	*1,180*	US $	1,932	2,768	3,604
Maintenance	US $	*590*	*885*	*1,180*	US $	669	951	1,220
Total Annual Costs	US $	6,780	7,470	8,985	US $	9,955	11,254	12,700
Cost per kilometer	**US $**	**0.42**	**0.31**	**0.28**	US $	**0.62**	**0.47**	**0.40**
Fixed cost per kilometer	US $	0.36	0.24	0.21	US $	0.46	0.31	0.25
perating cost per kilometer	US $	0.07	0.07	0.07	US $	0.16	0.15	0.15

Source: Author's calculation from the following sources: (AAA, 2002; ADAC, 2002; APTA, 2006b; FHWA, 2006; FTA, 2003; VDV, 2002)
PPP Germany (Euro) U.S. Dollar = 0.959 (Source: OECD, PPPs for GDP - Historical Series)

Table 4.2 shows that depreciation of the value of a car accounted for a large percentage of ownership costs in both countries in 2002. The German ADAC and U.S. AAA provide an additional category labeled "*other ownership costs*", which includes registration fees and insurance coverage. These amounted to an average of $2,000 for all mileage categories in the U.S., and about $3,000 in Germany. Unfortunately, this category is not broken up into insurance or registration fees/taxes.

Clearly, the largest difference in automobile related costs between the two countries was operating cost per kilometer. While *total* costs per kilometer driven were

[42] The mileage compared here is high for Germany, as the average German travels about 11,000 km in a car per year. Unfortunately, 16,000 kilometer annual mileage is the lowest value avaiable for the U.S. data.

about 50 percent higher in Germany than the U.S. for all mileage categories, *operating* costs per kilometer driven were twice as high in Germany for all of these mileage categories.

Operating costs for automobiles that are twice as high as in the U.S. clearly may deter car use in Germany. This difference is driven by gasoline taxation, which is a choice of public and fiscal policy. Individuals often only consider the operating costs of an automobile and not the fixed costs, when choosing between a car and another mode of transportation. The implication is that the marginal cost of driving, e.g. the cost of gasoline, may weigh more in the decision than the average cost for a kilometer driven, which would also include the fixed cost. In public transportation, the transit ticket comprises fixed and operating costs for transit users. Cheaper gasoline prices are therefore a great incentive to choose the car over transit. The next section introduces transit costs.

4.3 Costs of Public Transportation

In contrast to higher costs for automobile ownership and use, transit fares are on average lower in Germany than in the U.S. In the year 2000, the average fare per kilometer of transit use was 10 U.S. cents in Germany compared to 11 U.S. cents in the U.S. (adjusted for PPP) (APTA, 2006b; FHWA, 2006; VDV, 2002). The average, however, hides variability across transit modes, ticket type and regions within the countries. For example, in both countries, the average fare for one kilometer of local bus service was higher than for commuter and heavy rail. In 2002, the cost per passenger-km of heavy and commuter rail transit was six U.S. cents in Germany and 10 U.S. cents in the U.S. (APTA, 2006b; VDV, 2002). The explanation for this disparity might lie in longer average trip distances or more limited stops by rail than by bus. For example, the average trip distance was 22 km for rail and five km for bus transit in Germany for 2005 (VDV, 2006)).

In both countries, all levels of government provided subsidies for transit tickets for certain groups of riders. In Germany, school children, the elderly (66 and older), and people with disabilities can purchase tickets at a reduced rate. Similarly, in the U.S. reduced fares for the elderly and people with disabilities exist. School children in the U.S. generally do not use public transportation services (with the exception of large urban school districts), but ride special school buses provided by the school district at no cost to the rider at the time of use.

In 2005, many transit operators in metropolitan areas in the U.S. and virtually all operators in Germany offered annual, monthly, and weekly tickets at discount prices. These tickets provided a significant incentive to use public transportation because the marginal costs of an additional transit trip fall to zero once the ticket is purchased[43].

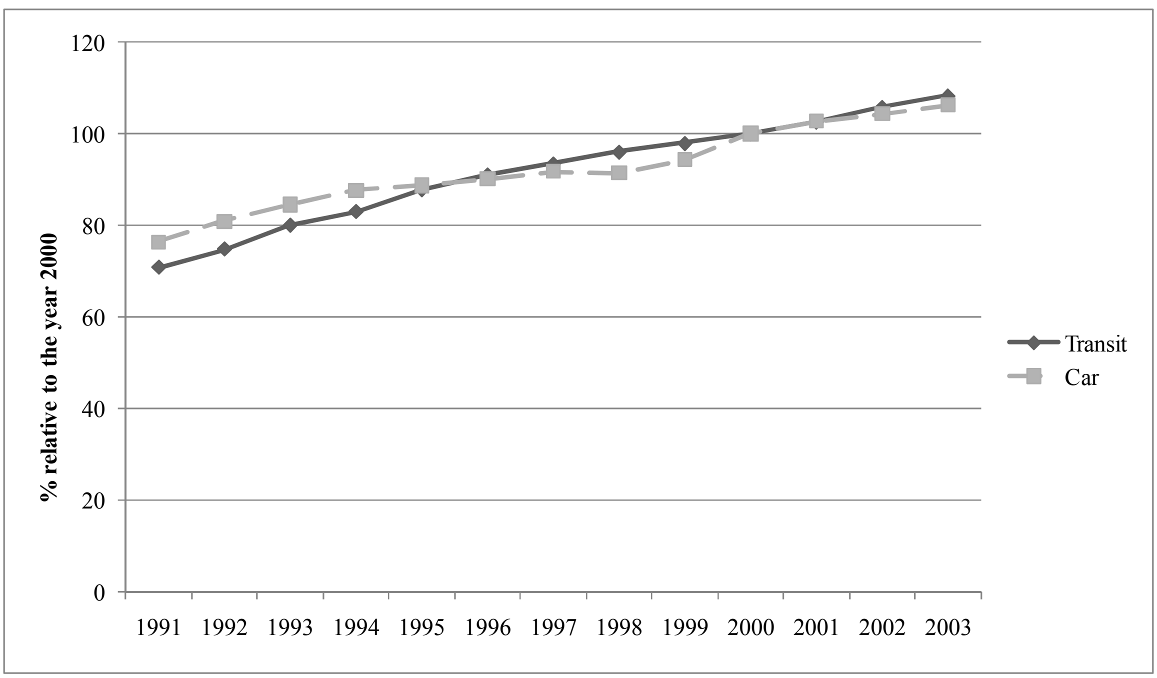
The same is true for region-wide tickets offered by German regional transit authorities. These tickets allow customers the use of all transit services within a region with one ticket within a given time frame. Each additional trip within the time frame comes at zero marginal cost. In most U.S. metropolitan areas, intermodal transit tickets do not exist, and a passenger has to pay extra for switching between transit operators (see section on transit supply for more details). Overall, subsidies for the operation of transit services were higher in the U.S. than in Germany. On average, since the year 2000 about 60 to 65 percent of the operating budgets of transit agencies have come from government

[43] Once the ticket is purchased an unlimited number of trips can be made within the time of validity.

financial assistance in the U.S., compared to about 30 percent in Germany[44](APTA, 2006b; VDV, 2002, 2005, 2006).

Due to the increases in the gasoline tax in Germany during the 1990s, one might assume that the cost of using transit has fallen compared to automobile operating costs. Surprisingly, this is not true. Exhibit 4.7 compares the price of transit fares to automobile operating costs relative to the year 2000. It shows that from 1991 to 2003 transit fares increased at a slightly faster rate than automobile operating costs, which means the increases in gasoline taxes during the 1990s have not translated into a price advantage for transit compared to the automobile.

Exhibit 4.7 Trend in Transit Fare and Automobile Operating Costs in Germany, 1991 - 2003 (relative to 2000 levels)

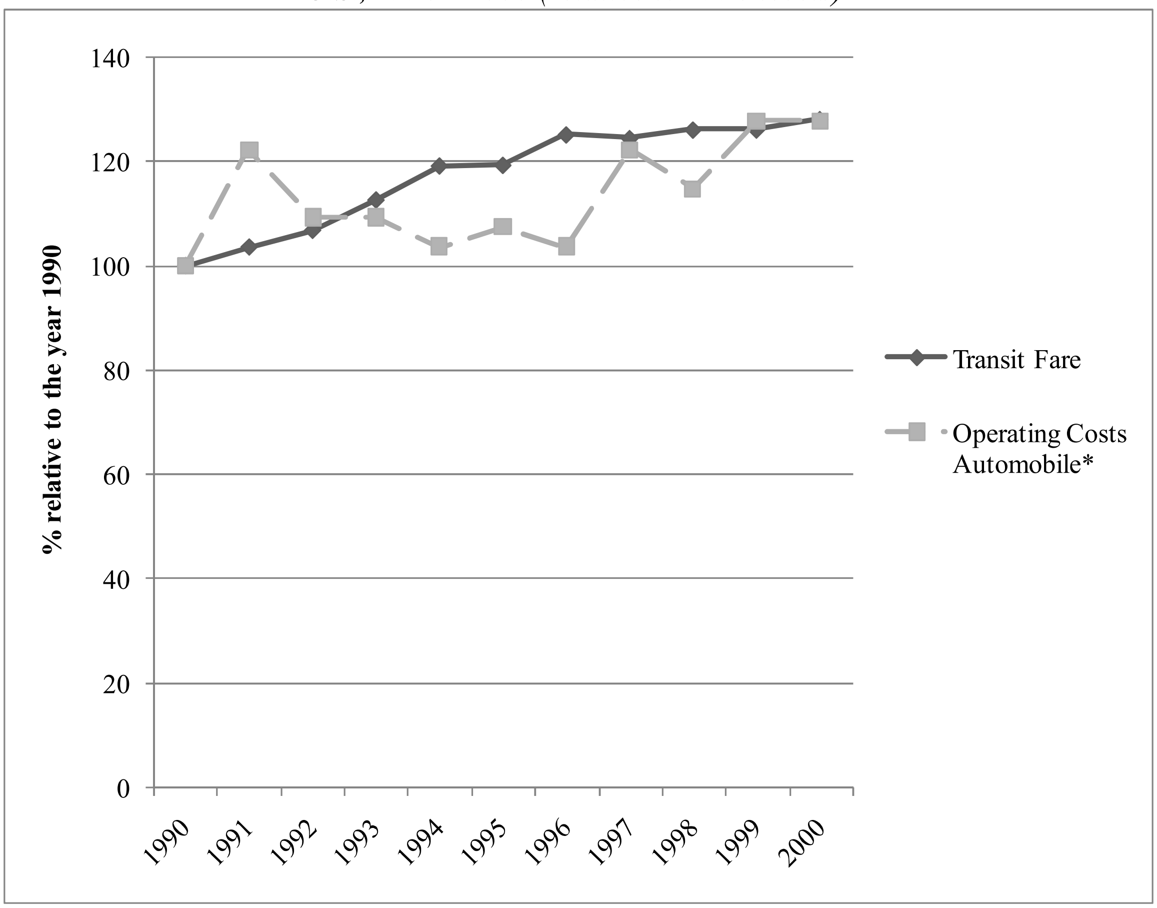


Source: (DIW, 2005b)

[44] This share excludes subsidies for heavy rail commuter trains in Germany.

In the United States the costs for transit and automobile operating costs also increased at about the same rate from 1990 to 2000 (see Exhibit 4.8) Compared to 1990 levels, transit fares and automobile operating costs were about 25 percent higher in the year 2000. In both countries the relative price difference between transit and auto use has therefore remained stable since 1990.

Exhibit 4.8Trend of Transit Fares and Automobile Operating Costs per Kilometer in the U.S., 1990 - 2000 (relative to 1990 levels)



Source: (APTA, 2006b; FHWA, 2006)
**Operating costs for the year 2000 is the average of the years 2000 and 2001*

4.4 Household Transportation Expenditures

Data from national consumer expenditure surveys in Table 4.3 show that Americans spend a higher percentage of their household income on transportation than

Germans. In 2000 and 2003 U.S. households spent slightly more than 19 percent of their disposable income on transportation. German households, on the other hand, spent only about 14 percent of their disposable income on transportation. Compared to German households, U.S. households spent over 30 percent more of their disposable income on transportation in 2000 and 2003. The share of a household's disposable income used for housing and food was about the same in both countries.

However, the share of disposable income allocated to transportation expenditures might not be the most reliable measure. Taxes on income are, on average, higher in Germany than in the U.S. In return, the German federal government provides many services for its citizens at low or no cost. For example education and health care. Income taxes in the U.S. are lower, but private households pay considerable amounts for health care and education. Disposable income in the U.S. has to be used for education and health care, while German households already "*pay*" for this via higher income taxes.

Transportation expenditures measured as share of gross household income can adjust for these discrepancies. In 2003, the average U.S. household spent 15.3 percent of its gross income on transportation (U.S. Department of Labor, 2003). German households spent only 9.9 percent of their gross income on transportation (DESTATIS, 2003a). As expected, the gap between U.S. and German households is larger for gross than for disposable income. On average, U.S. households spent over 50 percent more of their gross income on transportation than their German counterparts.

There are several explanations for the higher share of expenditures going towards transportation in the U.S. First, U.S. households own more automobiles, therefore depreciation costs and insurance for multiple cars add to higher transportation costs[45]. Second, American households enjoy cheaper costs per kilometer driven in an automobile, but the much higher level of car use, Americans drive an average of twice as many kilometers per year as Germans, offsets the relatively cheaper operating costs per kilometer. This suggests that lower costs of transportation may provide an incentive for or be correlated with much higher levels of transportation consumption. Lastly, transportation expenditures include all transportation consumed annually and may include a higher number of airplane or long distance trips in the U.S. than in Germany, adding additional costs to transportation. It was not possible to extract precise numbers, but the effect of long distance flights within the U.S. could be potentially offset by more frequent long distance vacation flights taken by Germans.

Table 4.3 Transportation's Percentage Share of Total Household Expenditure in Germany and the U.S.

	U.S.		**Germany**	
Year	*2000*	*2003*	*1998*	*2003*
Transportation	19.5	19.1	13.7	14.4
Housing	32.4	32.9	32.5	32.2
Food	13.6	13.1	13.9	14
Health	5.4	5.9	3.7	3.7
Other	29.1	29	36.2	35.7

Sources: (APTA, 2006b; DESTATIS, 2000, 2003a; FHWA, 2006; U.S. Department of Labor, 2000, 2003)

4.5 Government Subsidies for Transportation Supply

Clearly, the choice of transportation mode and the intensity of its use do not only depend on price, but also on access to highways and transit services. In both Germany and the U.S., as with subsidies for transit riders, all levels of government play a

[45] As of 2002, 60 percent of U.S. households owned twoor more cars, compared to only 27 percent of German households. In addition, there were only eight percent of U.S. households without an automobile in 2002, comapred to 19 percent carless households in Germany.

significant role in building road and transit infrastructure and in subsidizing road maintenance and transit service provision.

4.5.1 Financing of Roads and Transit in the U.S.

In the U.S., before WWII, funding and planning for road infrastructure was mainly in the hands of municipalities and states. There was only a marginal level of federal involvement in cost sharing for road construction, which was mainly related to mail delivery routes. These subsidies generally required a 50 percent match from local or state funds (Dunn, 1981; Weiner, 1996). The Federal Highway Act of 1944 authorized the construction of a 40,000 mile super highway system (foundations of the later Interstate Highway System). The level of federal funding stayed at 50 percent, requiring local or state governments to fund the other 50 percent (Dunn, 1981). The post-war years witnessed a boom in construction of state highways (especially turnpikes[46]), but national interstate construction activity remained slow. The Federal Highway Act and the Federal Highway Revenue Act, both of 1956, changed this, mainly by altering the matching ratio for interstate highways to 90 percent federal and 10 percent local. The matching ratio for secondary roads, not part of the Interstate system, stayed at 50 percent (Dunn, 1981; Weiner, 1996). Highway construction and federal subsides skyrocketed. A portion of the federal subsidies came from the Federal Highway Trust Fund, which was, as in most states, fed by earmarked gasoline and other taxes and fees from road users (Dunn, 1981; Yago, 1984). More roads led to more road users, which meant that more highway fees and gas tax revenues could be directed toward even more road construction (Dunn, 1981; Weiner, 1996).

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[46] Tolled roads.

While road construction was heavily subsidized, public transportation was privately financed and was almost completely neglected by the federal government until the 1960s. After WWII, the nation's transit infrastructure was in need of repair and investment due to heavy use during the war (TRB 2001). Transit system owners did not have money to invest and maintain their infrastructure and rolling stock, especially as they experienced increasing competition from automobiles. As a result, many transit providers raised fares, neglected necessary repairs, cut back services, and in some cases finally went out of business. It was not until the mid 1960s that the federal government, with the Urban Mass Transportation Assistance Act and the founding of the Urban Mass Transit Administration, stepped in and subsidized transit (Dunn, 1981; Pucher & Lefèvre, 1996).

In the 1970s, awareness of the negative externalities of automobile use increased. Fuelled by environmental problems, frustration with highway construction in urban areas, price shocks, and the economic reverberations of the two OPEC oil embargos, governments increased funding for transit. At the same time, the growth rate for funding for roads and road construction started to decline. The Federal Highway Act of 1973 for the first time allowed one-fourth of the Highway Trust Fund (moneys earmarked for urban roads) to be used for the purchase of buses (Dunn, 1981). The same act also allowed the federal share of funds for transit infrastructure projects to be increased to 80 percent. Furthermore, all metropolitan areas of more than 50,000 inhabitants were required to establish Metropolitan Planning Organizations (MPOs), which were also to be funded by a small part of the Highway Trust Fund. MPOs were viewed as a potential key to integrated regional planning for all modes of transportation (NJTPA, 2006; Weiner, 1996). During this period, funding for public transportation increased dramatically (Dunn, 1981). However, according to Pucher and Lefevre (1996), as a result of cost management in the transit industry most of the money was wasted on expensive and poorly planned new transit projects. During the 1980s, the Reagan administration cut federal subsidies for transit. State and local governments tried to fill that void, but overall subsidies for transit increased at a slower rate (Pucher & Lefèvre, 1996).

4.5.1.1 Changes to Transportation Financing and Planning in Recent Federal Transportation Bills: ISTEA, TEA-21 and SAFETEA-LU

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 opened a new chapter in U.S. transportation policy, which was continued by its successor the Transportation Equity Act for the 21st Century (TEA-21) of 1998. ISTEA and TEA-21 intended to change U.S. federal transportation policy in important aspects, but many of the Acts´ ambitious policies did not materialize as intended (Katz, Puentes, & Bernstein, 2003). Katz et al. (2003) summarize the goals of ISTEA and TEA-21s as follows:

- First, MPOs had never realized their intended planning and implementation responsibilities and instead had developed to be mainly research organizations. ISTEA established more responsibility, financial resources and more potential for MPOs to actually steer transportation planning in metropolitan areas.
- Second, ISTEA increased funding for transportation across the board and assured that gas tax revenues could not be diverted from surface transportation. It also assured that a considerable amount of federal gas tax flowed back to the states where it originated.

- Third, funding previously earmarked for road transportation was made more flexible. Now states and MPOs had greater flexibility to fund non-road project out of the funds given to them for road infrastructure projects.
- Fourth, a series of targeted programs was established to ease congestion and improve air quality. Additional programs were introduced to link transportation and land-use planning.
- Fifth, the legislation required planners to include societal, environmental and economic concerns when analyzing mobility related problems.
- Sixth, the laws required early and ongoing citizen participation in transportation decision making.
- Seventh, the Bureau of Transportation Statistics was created to enhance planning and public access to transportation related information.

These objectives were laudable, but not all came to fruition. In many cases, State Departments of Transportation (DOT) maintain considerable veto powers over MPOs and some have even stricter control. Additionally, the share of funding going to MPOs relative to that of rural areas declined during ISTEA and TEA-21 legislation, rather than increasing as intended. Even though the federal contribution for major highway and transit projects is typically 80 percent, many transit projects reported lower federal shares. Furthermore, many transit projects reported difficulty in obtaining additional funding, while state gasoline tax revenues were still earmarked for road transportation projects. Overall, states rarely used the funding flexibility they were given. Of the $50 billion potentially available for alternative and innovative projects under this legislation only $7 billion were spent on transit and other alternatives (Katz et al., 2003). Citizens were also not included in transportation decision making to the extent prescribed by the legislation.

In 2005, President Bush signed the Safe, Accountable, Flexible, Efficient Transportation Equity Act—A Legacy for Users (SAFETEA-LU) into law. It prescribes a volume of $286 billion in transportation spending through 2009. In most aspects this new legislation is a continuation of ISTEA and TEA-21. Transit will receive $53 billion, and the ratio of highway to transit funding remains unchanged. The new legislation provides additional resources for the promotion of walking and cycling and it makes funds of some programs more flexible, such as Congestion Mitigation and Air Quality (CMAQ) funds. It contains 5,145 earmarked projects worth $15 billion of federal dollars plus the required local matching money. Trends and changes in funding for different modes of transportation are shown in the next section and additionally in the section on bicycling and non-motorized transportation further below.

Table 4.4 shows the trend in the level of government funding for roads and public transportation from 1970 to 2004. From 1970 to 1980 subsidies for public transportation increased 12-fold and then 3-fold from 1980 to 2004 in current dollars. Adjusted for inflation the increases are still substantial: 7-fold from 1970 to 1980 and 1.7-fold from 1980 to 2004.[47] From 1990 to 2004, government subsidies for capital investments for transit grew almost 3-fold, indicating increased involvement of government in the construction of new and expansion of old transit systems since ISTEA legislation in 1991. In 2005, sixty percent of the funds used for the operation of transit services came from local, state or federal governments (APTA, 2006). For the fiscal year 2006, the

[47] Calculated using the Bureau of Labor Statistics CPI Inflation Calculator online at: http://data.bls.gov/cgi-bin/cpicalc.pl. Accessed on 14 Januaray 2007.

federal government appropriated $8.5 billion for public transportation under the new SAFETEA-LU legislation. This is an 11 percent increase over the previous fiscal year and an all time record for funding for public transportation (APTA, 2006a).

The growth of subsidies for road transportation has been less dramatic. Since 1970, the subsidies from all levels of government for road transportation have increased 6-fold in current dollars (1.45-fold adjusted for inflation). Government revenues from the gasoline tax, user fees, and tolls increased 8-fold in current dollars between 1970 and 2004 (1.7-fold adjusted for inflation), slightly higher than the growth in expenditures for roads. Table 4.4 shows that from 1970 to 2004 road subsidies were always at least twice the subsidies for transit; in 1970 subsidies for roads were 20 times the share of transit subsidies.

Table 4.4 Trends in Government Subsidies and Support for Roads and Public Transit in the U.S., 1970-2004 (amounts in current $ millions)

	1970	**1980**	**1990**	**1995**	**2000**	**2004**
Highway User, Taxes, Fees and Tolls	10,248	17,177	44,172	59,562	81,006	83,006
Government Expenditure on Roads	20,835	41,795	74,885	92,504	127,459	147,489
Government Subsidy to Roads	*10,587*	*24,618*	*30,713*	*32,942*	*46,453*	*64,483*
Government Subsidy to Transit	*518*	*7,139*	*14,203*	*15,858*	*20,867*	*28,229*
Capital	n.a.	n.a.	4,936	7,230	9,587	13,246
Operating	n.a.	n.a.	9,267	8,628	11,280	14,983

Sources: (APTA, 2006b; FHWA, 1990-2008; Pucher & Lefèvre, 1996)

Tables 4.5 and 4.6 show trends in road and public transportation supply between 1970 and 2004. While the level of transit supply measured in vehicle kilometers of transit service more than doubled from 1970 to 2004, the number of unlinked transit passenger trips only grew by 50 percent. This indicates that supply of transportation increased faster than demand.

Table 4.5 Trends in Supply and Demand of Public Transportation in the U.S., 1970-2004 (all amounts in millions)

	1970	1980	1990	1995	2000	2004
Vehicle km of Public Transport Service	3,013	3,635	5,186	5,680	6,529	7,153
Public Transport Passenger Trips	6,172	6,626	8,799	7,763	9,363	9,575

Sources: (APTA, 2006b; Pucher & Lefèvre, 1996)

For road transportation the picture is just the opposite. The total length of urban roads grew by 65 percent between 1970 and 2004, but kilometers driven by car and light truck on urban roads more than doubled. In this case demand increased much faster than the supply of roads. The fast growth of vehicle kilometers of travel of SUVs and light trucks since 1995 is especially impressive.

Table 4.6 Trends in Supply and Demand of Urban Road Transportation in the U.S., 1970-2004

	1970	1980	1990	1995	2000	2004
Length of urban roads	989	997	1,211	1,319	1,373	1,579
Car and Light Truck km on Urban Roads	912	1,365	2,040	2,267	2,529	2,872
car km urban roads	n.a.	n.a.	n.a.	1,611	1,622	1,834
2axle other km urban roads	n.a.	n.a.	n.a.	656	907	1,038

Source: (FHWA, 1990-2008; Pucher & Lefèvre, 1996)

4.5.2 Financing and Trends of Supply and Demand of Roads and Transit in Germany

As of 2005, the construction, operation, and maintenance of roads and transit in Germany are financed by all levels of government. The federal government plays a key role in funding transportation infrastructure and rail transit operation.

Since the passage of the "*Federal Municipal Transportation Finance Law (Gemeindeverkehrsfinanzierungsgesetz (GVFG))*" in 1967, the German federal government has provided funds to state and local governments for capital investments. GVFG funds have to be matched by local governments and originate from the mineral oil/ gas tax revenues. From 1967 to 2004, over €57 billion (U.S. $71.3 billion) of GVFG funds were disbursed: €26 billion (U.S. $ 32.5 billion) for local roads, €31 billion (U.S. $39 billion) for public transportation, and €0.1 billion (U.S. $ 125 million) for federal transportation research (BMVBS, 2005a).

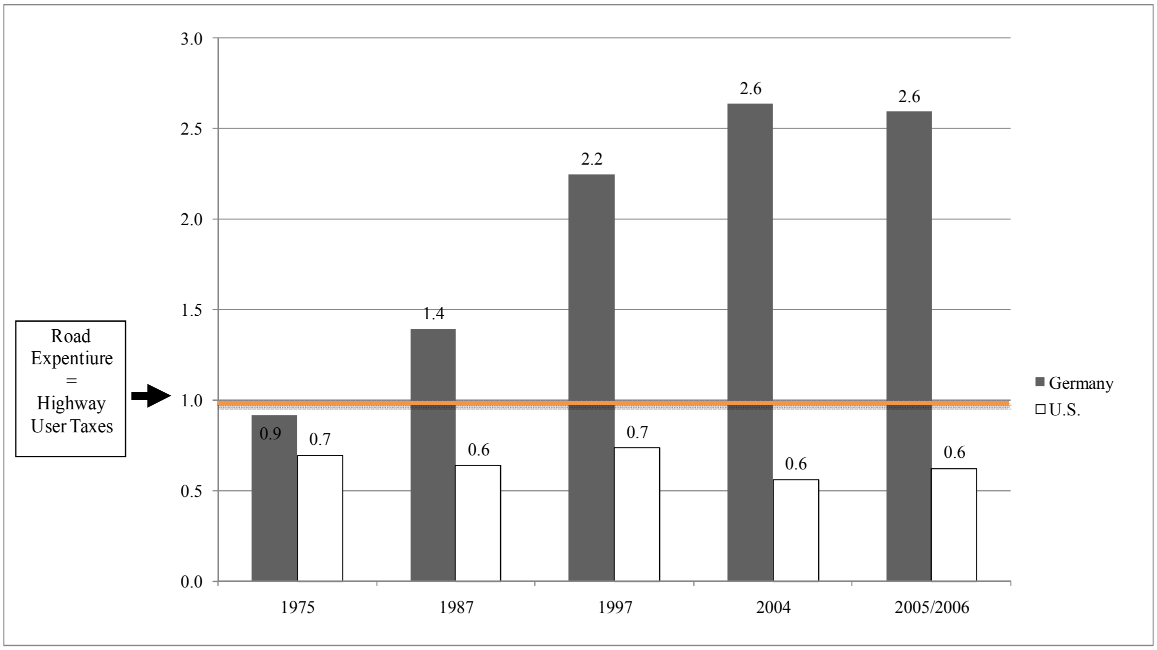
The exact annual amount, matching ratio, and composition of the funds has changed several times since 1967. Originally, 60 percent of the funds were used for local road projects, but over time the ratio shifted in favor of transit, as more and more funds dedicated for roads became eligible for transit use. Since 1987, 30 percent of road funds can be transferred to public transportation purposes by local and state governments (BMVBS, 2005a). Originally, states had to include the federal government in their deliberations on how to use the funds. This changed in 1985, and since then the federal government only has to be informed once a decision is made.

German reunification in 1990 and policy changes in the 1990s also had an impact on the GVFG. In the early 1990s, some transportation projects in East Germany were fully funded by the federal government. Successive changes of the law during the 1990s made more purposes eligible for GVFG funds (such as rail rolling stock, park and ride facilities, and measures to improve the speed of transit services). Additionally, the federal government gave local and state governments more flexibility in deciding exactly how to use the funds. Since the beginning of the 1990s, the federal government has directly funded specific local rail projects through GFVG moneys. In order to be eligible for GVFG funds, local and state governments have to demonstrate that their projects are included in local transportation plans, are in line with spatial development goals, address the needs of the disabled and elderly, and that they have secured matching funds (BMVBS, 2005a).

Including all other funding sources, from 1999 to 2003, the federal government spent €78 billion (U.S. $94 billion) on transportation projects in Germany. Most of the funds were spent on roads and regional rail (BMVBS, 2003a).

As shown above (Table 4.4), in the U.S. revenues generated from road travel do not suffice to cover the annual expenditures for roads, leading to net government subsidies for road construction and maintenance. The situation in Germany is opposite. Data on government spending on roads in Germany are sparse. Exhibit 4.9 shows that since at least 1987, revenues from the gas tax and vehicle registration have been greater than government expenditures on roads in Germany. In 1975, all levels of government still subsidized highways, as receipts from fuel taxes and registration fees were less than government expenditures on roads. In 1987, receipts from road users exceeded highway spending by €4.6 billion. In 2005, revenues from road users in Germany exceeded expenditures by 2.6 to 1. In the U.S., government expenditures for road transportation have always exceeded road user revenues by 30 to 40 percent.

Exhibit 4.9 Highway User Taxes and Fees as Share of Road Expenditures by All Levels of Government in Germany and the U.S.



Source: (BMVBS, 1991-2007; FHWA, 1990-2008)

4.5.2.1 The National Transportation Plan - Bundesverkehrswegeplan

Another pool of funds is used for projects outlined in the Federal Transportation Plan (Bundesverkehrswegeplan). This plan is drawn up in collaboration with the German states and is often described as a "*wish list*" of state transportation planners[48]. From 1950 to the early 1970s the goal of the Federal Transportation Plan was primarily to foster reconstruction and economic growth. With the Federal Transportation Plan of 1973, the focus shifted to also include societal goals, such as reducing traffic fatalities, energy use, loss of open space, and other environmental problems (Koeberlein, 1997). Since the mid 1970s, the federal government has encouraged the coordination of transportation planning across modes and jurisdictional boundaries. Federal programs and regulations

[48] This is similar to U.S. tranportation improvement program lists (TIP), where MPOs rank and prioritze their intended investments.

have helped reduce the number of traffic deaths and the amount of vehicle emissions (Koeberlein, 1997).

This shift in policy could not only be found at the federal level, but at all levels of government. Local governments have implemented traffic-calming schemes, car-free pedestrian zones in city centers, parking restrictions for automobiles, right of way priorities for transit, expanded bicycling networks, and integrated transit planning and service provision (Hass-Klau, 1993b; Pucher & Lefèvre, 1996) (see section on local policies below).

4.5.2.2 History and Recent Changes in Funding of Public Transport

Before WWII, transit in Germany was provided by local governments as local monopolies. Revenues from transit were used by municipalities to subsidize other city services (Baron, 1995). After WWII, as a result of pressure from an influx of millions of refugees[49] the federal government started subsidizing the construction of single and two-family homes. Most new houses were built outside of already existing settlements and not along transit corridors. The increasing popularity of the car, the success of the German car industry, and a more dispersed settlement structure led to a decline of transit ridership (Baron, 1995; Yago, 1984). Similar to the U.S., German transit operators cut services, raised prices, and lost riders. Since then, many municipalities have cross-subsidized their transit services through other local services, such as water works or local power utilities (Pucher & Lefèvre, 1996). In the early 1960s a federal government commission proposed financial aid from federal and state governments for public transportation infrastructure construction projects (eventually leading to the "*Federal*

[49] Mainly from the Eastern parts of the former German Reich (now Poland and the Czech Republic) and internally displaced peoples.

Municipal Transportation Finance Law (GFVG)").

Funding for public transportation infrastructure and operation comes from various sources within federal, state, and municipal governments. The plethora of programs and sources makes identifying exact funding streams very difficult, especially since the regionalization of rail transit services in 1994, which created different financing structures in all German states (Scholz, 2006). In general, operating subsidies for road-based public transit are financed by local governments. Special fare reductions for the elderly or school children for road-based transit, however, are borne by state governments.

Overall, capital and operating subsidies mainly come from the federal government, with additional matching funds from state and local governments (Pucher 1995). In 2001, $22 billion (about €18 billion) was spent on transit by all levels of government and transit riders in Germany. About two-thirds, or $15 billion (about €12 billion), came from all levels of government as subsidies for public transportation (Rönnau, Schallaböck, Wolf, & Hüsing, 2002; UBA, 2003a). This sum is comparable to other years and it includes operating subsidies and subsidies for investments in infrastructure and rolling stock. In 1993 and 1999, for example, all levels of government spent about $19.2 billion (€16 billion) on public transportation (Bundesregierung, 1999; Rönnau, 2004).

On average, one-tenth of these funds came from the federal government directly, two- thirds came from state governments and one fifth from local governments. A large portion of the state funds were comprised of transfers from federal to state governments (Rönnau et al., 2002). In 2005, the federal government spent $10.3 billion (€8.6 billion) on public transportation (€7 billion of regional transportation funds and €1.6 billion of GVFG funds) (VDV, 2005).

4.5.2.3 Legislative Changes in the 1990s

Two major legislative changes in the mid 1990s influenced public transportation in Germany. First, responsibility for rail transit was handed from the federal to state governments. Second, EU requirements (EU 1191/69) led to changes in German public transportation laws requiring deregulation of local transit markets and more competition (Bundesregierung, 1999; Scholz, 2006).

Until 1996, public rail transportation was directly financed by the federal government. With regionalization of rail transit in 1996, management and operation responsibilities, together with financial resources, were handed over to state and local governments. All German states passed new state transportation laws and founded state-wide transit organizations responsible for coordination of transit in the state. All states introduced new coordinated timetables (Taktfahrplan) for rail transit with the goal of integrating all transit operations. This proved successful in increasing regional rail ridership.

On the local level, municipalities or regional transit authorities compile transit plans and coordinate timetables, levels of service, and fares for transit in their districts and within the broader transit authority area. Municipalities and transit authorities are required by law to establish transit plans, timetables, and integrated fare systems. They are legally obliged to issue calls for tender for all *subsidized* transit[50] lines/routes, but not for unsubsidized lines (Bundesregierung, 1999). In practice, calls for tender are rarely

[50] Subsidized transit lines do not operate at a profit (e.g. operating costs are higher than fare box revenues collected).

issued as municipalities still cross-subsidize their transit service with profits from local energy and water utilities (Van de Velde, 2003).

Table 4.7 Trend in Demand and Supply of Road Transportation in Germany, 1950 - 2003

		1950	1960	1970	1980	1990	Unified Germany 1991	1995	2000	2003
Length of "non-local" Road Network (in 1000 km)	Germany	176	181	210	220	221	226	229	231	231
	West Germany	129	135	162	172	174	174	174	174	175
	East Germany	47	46	48	48	47	52	55	57	57
Length of Local Road Network (in 1000km)	Germany						410	n.a.	n.a.	n.a.
	West Germany	220	227	270	310	327	n.a	n.a	n.a	n.a
Passenger Kilometers of Car Travel (billion)	Germany						714	836	855	872
	West Germany			380	477	602	n.a	n.a	n.a	n.a

Source: (BMVBS, 1991-2007; Heidemann et al., 1993)

Table 4.7 displays trends in road transportation demand and supply in Germany since 1950. Wherever possible, trends in East and West Germany are presented separately. Leading up to WWII, the fascist regime expanded the German local and non-local road network to promote their vision of an automobile society and to prepare for the war. They had completed 4,000 kilometers of the Autobahn network (a high speed limited access highway network) by 1941.

In West Germany, after WWII, the road network was rebuilt and later expanded. From 1950 to 1980 the non-local road network in West Germany was expanded by 20 percent and the length of the local road network grew by 41 percent. Similar to the U.S. data presented earlier, passenger kilometers of car travel grew even faster than road networks were expanded. From 1970 to 1990 passenger kilometers traveled by car on roads and highways grew by 60 percent.

In East Germany the length of non-local roads was stable from 1950 to 1990. After reunification it was expanded and upgraded, as most roads were in deplorable condition. Upgrading and expanding the East German road network was part of a larger 20-year reconstruction project for all modes of transportation in East Germany (Verkehrsprojekte Deutsche Einheit). From 1992 to 2012, about €35 billion (U.S. $ 43 billion) were planned for investment in upgrading East German federal highways and reconnecting East and West Germany within this reconstruction effort (BMVBS, 2003a). Roehl (2000 cited in (Sichelschmidt, 2004)) estimates that in 1990, only 45 percent of roadways in East Germany were in a good state of repair and that 40 percent of bridges and 66 percent of local roads were in disrepair. From 1991 to 2002 a total of €53 billion (U.S. $66 billion) of federal funds were invested in the East German transportation system (Sichelschmidt, 2004) (€132 billion for all of Germany ($211)).

Beginning in 1990, the length of the non-local road network was expanded in East Germany, while it remained stable in West Germany. Nonetheless, passenger kilometers of car use increased by more than 20 percent from 1991 to 2003 for Germany as a whole. A big part of this increase occurred on local roads. Unfortunately, data about trends on the length of the local road network are not available for the years after 1991.

Table 4.8 Trend in Supply and Demand of Public Transportation in Germany, 1970-2003

					Unified Germany			
		1970	1980	1990	1991	1995	2000	2003
Vehicle Kilometers of Road Public Transport Service (Billion)	Germany				3.8	3.7	3.9	3.74
	West Germany	1.85	2.61	2.96				
Vehicle Kilometers of Rail and Road Public Transport Service (Billion)	Germany					4.7	4.78	4.7
Passenger Kilometers of Rail Transit Travel (Billion)	Germany				23	35	39	40
	West Germany	16	15	17				
Passenger Kilometers of Road Transit Travel (Billion)	Germany				82	77	76	76
	West Germany	58	74	65				
Passenger Kilometers of Total Transit Travel (Billion)	Germany				105	112	115	116
	West Germany	74	89	82				

Source: (BMVBS, 1991-2007; Heidemann et al., 1993; VDV, 2005)

Table 4.8 displays trends in supply and demand of public transportation in Germany. Supply of public transportation services on roads, measured in vehicle kilometers of transit service, increased by 60 percent from 1970 to 1990 in West Germany. During the same time period, road-based transit demand, measured as passenger kilometers of travel, only grew by 12 percent. From 1991 to 2003, total road transit vehicle and passenger kilometers for reunified Germany declined slightly. In contrast to the decline in road transit supply and demand, rail transit displayed an increase of vehicle kilometers of service and passenger kilometers from 1991 to 2003. Unfortunately, the available data is not necessarily comparable over time due to changes in the organization of regional rail service during the mid 1990s. For example, data prior to 1997 exclude rail transit provided by the former nationally owned German Railways.

4.6 Transportation Policies on the Local Level and Non-Automobile Travel

Besides the aggregate trends in transportation policies described above, there are myriad local policies that influence travel behavior. Due to their local nature, they cannot easily be aggregated, quantified, and compared across countries. The following sections summarize the most important policy trends at the local level in Germany and the U.S. These include: efforts to increase cycling and walking, traffic calming, car-free pedestrian zones, parking management, right of way priorities for transit, regional coordination of public transportation services, integration of transportation modes, and increased safety for non-motorized transportation.

4.6.1 Promoting Cycling in Germany and the U.S.

Since the 1970s German cities have made impressive efforts in promoting bicycling and increasing its mode share and safety. During this time, many cities started to build local bicycle networks, install bike parking facilities at train stations, and modify intersections with special bike traffic lights or advanced stop lines to accommodate the needs of cyclists. Local transit operators also began to allow bikes on trains and buses (Pucher & Dijkstra, 2003).

Many German cities created car-free zones at the center of their cities, which only allow for transit and non-motorized transportation modes (Pucher, 1995b; Pucher & Dijkstra, 2003). Additionally, many German cities chose to implement traffic calming in residential neighborhoods, by slowing car traffic down to 19 mph (see section below). Cyclists can easily share the road with slow moving cars in residential streets with low traffic volumes. Small cities like Freiburg (population 170,000) or large cities like Berlin (population 3.4 million) have traffic-calmed most of their residential neighborhoods and therefore a large percentage of all urban roadways (Banister, 2005; Bratzel, 2000; City of Berlin, 2006; City of Freiburg, 2007).

From the early 1970s to the early 1990s, cycling experienced a boom and many cities reported a doubling of their bike mode share. The City of Munich, for example, increased its bike share from six percent in 1976 to 13 percent in 1996 (Socialdata, 2006). The German Federal Ministry of Transportation reports population-weighted bike shares by city size categories for the year 2003, ranging from an average of nine percent for cities with more than 500,000 inhabitants to 15 percent for cities with less than 100,000 inhabitants (BMVBS, 2006). Currently every German cycles one kilometer a day[51], compared to 0.1 kilometer for Americans. As was discussed in Chapter 2, bicycling mode shares in the U.S. are much lower than in Germany (1 percent vs. nine percent of all trips). Only a few American cities have extensive networks for cycling or bike parking facilities (e.g. Madison, WI and Davis, CA). No American city has promoted cycling to the extent German cities have since the 1970s.

4.6.1.1 New Federal Commitment in Germany and the U.S.

In Germany, early efforts to increase cycling have been mainly on the local level; federal government involvement has been limited to federal traffic laws protecting cyclists or making bike and pedestrian safety an integral part of the German driver's license test.

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[51] Even though bike mode shares increased dramatically over the last three decades bike injuries and fatalities dropped significantly. From 1991 to 2000 the number of bike injuries fell by 12 percent and the number of cyclists killed in traffic declined by 29 percent (BMVBS, 2006). These two trends might be functionally related. Jacobsen (2003) surveyed cycling and fatality data from different cities and different time periods and found that increased cycling levels and lower fatality and injury rates coincide (for details see section 4.5.5 on safety below).

More recently, the federal government has increased investment in bike paths and lanes along federal highways. From 1991 to 2000 for example, 3,600 km of new bike paths along federal highways were built for $603 million, bringing the length of bike facilities along federal highways to 15,060 kilometers.

In 2002, the federal government published its first national bicycling plan (Nationaler Radverkehrsplan), providing an integrated approach towards bicycling in Germany. The plan sets very ambitious goals and puts the bicycle as a mode of transportation at the heart of the German urban transportation system. It identifies increasing the bike share from 12 percent to 25 percent of all trips by 2012 as an ideal goal to help reduce Greenhouse Gas Emissions (GHG). Under the Kyoto protocol, Germany is committed to reducing CO2 emissions by 21 percent relative to 1990 levels (DIW, 2006). While overall GHG emissions in Germany declined from 1990 to 2000, GHG emissions from transportation sources increased.

The National Plan identifies the need to take an integrated approach to bicycle planning, including not only bike paths and lanes, but also bike parking, integration with other modes, and cyclist and car driver safety training (CEMT, 2004). This approach includes not only integration of cycling and transit use, like the large bike parking garages at the train stations of Muenster and Freiburg, but also changes in land-use planning promoting the concept of mixed-use, dense settlements (called "*the city of short distances*"). Shorter distances increase the feasibility of cycling.

The federal government doubled its earmarked funding for cycling to $120 million per year in 2002. It also allowed its transportation subsidies for local transportation projects (GVFG) to be used for bicycling facilities. It further proposed to create a German bicycling network of 10,200 km connecting existing local cycling networks. Ninety-five percent of the network length already exists; the program would fund connections between these local networks.

In the U.S., passage of ISTEA in 1991 and TEA-21 in 1998 substantially increased the involvement of the federal government in cycling. While federal funding for cycling was only about $2 million a year during the 1980s, it reached $413 million under TEA 21 (Pucher & Buehler, 2006). Similar to Germany, more funds originally earmarked for road or public transportation could be used for cycling projects. Clarke (2003) estimates that annually about $35 billion of federal transportation funds are potentially eligible for pedestrian and cycling projects, but state and local governments only use a fraction for cycling. ISTEA also required State Departments of Transportation to establish a permanent position for a pedestrian and cycling coordinator. Furthermore, state DOTs and MPOs must consider pedestrian and cycling needs in their 20-year long range and 2-year transportation improvement plans (Clarke, 2003). In 1994, the U.S. federal government set the goal of doubling the bike mode share (U.S. Department of Transportation, 2004).

Wilkinson and Channcey (2003) found that few state DOTs fully comply with the new regulations. From their own funds, states spent only $125 million on pedestrian and bike projects, mainly as matching funds for federal projects in 2000. This compares to $49 billion of state dollars spent on highways in 2004 (FHWA, 1990-2008) (Table HF-10).

The passage of SAFETEA-LU in 2005 made even more funds potentially eligible for pedestrian and cycling projects (America Bikes, 2006). From 2005 to 2009 there are

$4.5 billion available for pedestrian and cycling projects, and about $70 billion could potentially be used for cycling if all flexible funds were to be used for cycling and pedestrian projects (America Bikes, 2006). It remains to be seen if and how these funds will be used by state and local governments.

Interestingly, in Germany cycling has been promoted more vigorously on the local level, with the federal government only recently providing additional support. In the U.S. the situation seems to be the opposite, with the federal government acting as the leading force behind promotion and funding of bicycling, and state and local governments offering only limited support (Pucher & Buehler, 2006)[52].

4.6.2 Home Zones, Traffic calming, and Car-free Pedestrian and Reduced Speed Zones

Like most American cities, after WWII, German cities accommodated the automobile. They built downtown parking garages, widened streets in the city and allowed automobiles into the hearts of the cities. In the late 1960s, the negative impacts of car use in cities, such as noise and air pollution and loss of public space, became apparent (Baron, 1995). Since the early 1970s, German cities have implemented local policies to restrict car use in city centers and residential areas and promoted alternative modes of transportation. These measures include car-free pedestrian zones in city centers, traffic calming of residential neighborhoods, restrictions on car parking, improvements of public transportation service, and the promotion of cycling. U.S. cities have been much slower in embracing these measures, and even when they have done so, none have adopted these policies to the extent that German cities have.

[52] There are noteworthy exceptions such as the student towns/cities of Madison, WI, Boulder, CO or Davis, CA.

Since the 1970s, German cities have experimented with reduced speed zones (called "*Tempo 30 Zones"*). These are residential areas with relatively few physical traffic-calming alterations to the street design, but a drastically reduced speed limit for cars (19mph). These zones were widely implemented on the local level in the 1970s and especially the 1980s. In 1989 the federal government gave this local policy permanent federal law status (Hass-Klau, 1993b).

Most German cities, towns and villages have now incorporated "*Tempo 30 Zones*" on all residential streets throughout entire jurisdictions (Köhler, 1995). For example, about 80 percent of the roads in the cities of Bonn (310,000 inhabitants) and Munich (1.2 million inhabitants) and over 70 percent of the roads in the city of Berlin (3.5 million inhabitants) are now within reduced speed zones (City of Berlin, 2006; City of Munich, 2006a, 2006b; Hass-Klau, 1993b).

In the early 1980s, German cities began to import from the Netherlands the idea of traffic-calmed neighborhood streets using physical design features to limit traffic speed and volume. There "*Woonerven*" or Home Zones had proven successful in limiting local car traffic and accidents. Home Zones abandon the traditional separation of street and sidewalk and physically change the street layout to create one common living space in residential streets (Biddulph, 2001; Hamilton-Baillie, 2001). Cars have to drive very slowly in these areas and have to yield to pedestrians and cyclists at all times. Some German cities considered the alterations to the street surface and layout for Home Zones or other traffic-calming measures to be too expensive to be applied to larger areas. These cities preferred the more inexpensive option of extending "*Tempo 30 Zones*" (Topp, 1994, 1993).

"*Before and after*" studies showed that traffic calming reduced the number of accidents and their severity, the average driving speed, noise, pollution, communication deficiencies of residents, and parking problems (Hass-Klau, 1993a, 1993b). These local efforts were also accompanied by the "*Children and Traffic*" initiatives introduced by the federal government in 1980, including a law requiring drivers to be particularly aware of children, putting the burden of proof of innocence on the car driver in any accident involving a child.

Many German cities, towns, and villages also created car-free pedestrian zones. These zones consist of a system of roads with stores and shops usually in the Central Business District, which are off-limits to automobiles. Cars must be parked outside the zone. The zones are open to pedestrians and cyclists and sometimes to public transportation (Köhler, 1995; Pucher & Lefèvre, 1996). When the pedestrian zones were introduced in the 1970s, many local merchants were afraid of losing business, but in most cases their business has actually increased (Hass-Klau, 1993a, 1993b). Today, businesses in pedestrian zones advertise their location as especially appealing for customers. Around most pedestrian zones automobiles can be parked in parking garages within walking distance, therefore accommodating some motorists (see parking section below).

Since 1990, more and more U.S. cities and towns have also experimented with home zones (for example Asheville, NC, Boulder, CO, and West Palm Beach, FL), mixed pedestrian and transit zones (Madison, WI, Minneapolis, MN, Charlottesville, VA or Santa Monica, CA), and many have implemented traffic-calming schemes (Ewing, 1999; Ewing, Brown, & Hoyt, 2005). However these approaches are not nearly as extensive and widely applied as in Germany.

In 2005, Ewing and colleagues (Ewing et al., 2005) surveyed 21 "*leading jurisdictions*" in traffic calming. They found the typical budget earmarked for traffic calming to be between \$100,000 and \$250,000, but they also found that many jurisdictions operated on a shoestring budget (with the notable exception of Seattle, which spends \$600,000 a year on traffic calming). With three exceptions, all cities surveyed required votes by citizens (usually by mail) before traffic-calming plans were adopted and implemented. Ewing and colleagues found that the main reasons to not implement traffic-calming schemes were safety responders (ambulances and fire trucks) and the non-eligibility of non-local roads for traffic calming (Ewing et al., 2005).

4.6.3 Parking Management and Park and Ride

Free parking at the destination of a trip is a big incentive for car use (Manville & Shoup, 2004; Shoup, 1999, 2005). In the U.S., 95 to 99 percent of all car trip destinations offer free parking, constituting a major subsidy for automobile travel. Shoup (2004) calculated that free parking is a larger subsidy to car travel than free gasoline. His calculations are mainly based on the construction, maintenance, and opportunity costs of parking lots and garages.

On the regulatory side, many U.S. cities require developers to build a minimum number of parking spaces for new housing or business developments. In Germany, on the other hand, developers face a maximum number of parking spaces they are allowed to build. In some cases developers are even required to pay a fee to municipalities for building and maintaining on street parking spaces, public parking garages, and parking facilities at nearby transit stops (built and maintained by the municipality) (Topp, 1994).

Kenworthy (2002) compared parking in central business districts of seven large

German and ten large U.S. cities for the year 1995. He found that U.S. cities have twice as many parking spaces per 1000 jobs in the central business district (CBD): 560 compared to 220 parking spaces per 1000 jobs in Germany (Kenworthy, 2002).

Since the 1980s, German municipalities have made it a policy to reduce car parking in city centers and to make it more expensive (Boltze & Schaefer, 2005; Köhler, 1995). At the same time, they try to encourage and improve alternative modes of transportation, via improvements in public transportation or better cycling facilities. According to Topp (1994), German cities report mode changes towards non-automobile travel and ride sharing due to these "*parking management*" schemes. There are no aggregate national data on parking and parking management. A survey by the German Highway Institute (BAST, 2004) found that parking management schemes and parking fees vary widely across cities. Most parking management schemes are applied area-wide and set maximum parking time limits. Most schemes have special provisions and exemptions for residents. Many cities provide electronic parking guidance systems, giving information via electronic traffic signals on where motorists can find available parking spaces in the city (City of Freiburg, 2006; Köhler, 1995).

Additionally, many German cities encourage park and ride schemes by providing parking spaces at transit stops (City of Berlin, 2006; City of Freiburg, 2006; City of Munich, 2006a; Köhler, 1995). Köhler (1995) reports that park and ride facilities in the Frankfurt region made regional rail service viable and increased transit ridership into the city.

4.6.4 Planning Organization of Public Transport

The attractiveness of public transportation in Germany was additionally increased by improvements made to the operation and management of transportation services. In 1967 the region of Hamburg was the first in Germany to integrate planning and provision of transit services region wide in a so called "*Verkehrsverbund*". Most other German cities and regions have followed suit. Two regional transit authorities are especially remarkable: The *Verkehrsverbund Rhein Ruhr*, covering an area of over 7.5 million inhabitants, and the *Verkehrsverbund Berlin Brandenburg,* covering the entire land area of two German states. Virtually all regional transit authorities experienced increases in ridership in the long run. During the 1990s, some regional transit authorities in West Germany saw ridership increase by 20 percent (BMVBS, 1991-2007).

Regional transit authorities plan transit services, integrate timetables and fares, distribute operating subsidies over the different transit agencies, and assure a seamless public transportation system across the region. The passenger buys a single ticket and can use all transit services in the region. Usually the user does not even know that the provider of the transit service has changed when switching transit modes (Pucher & Chlorer, 1998). In most U.S. cities there is no regional ticket integrating multiple transit operators into one seamless system. Region wide monthly passes are a major incentive for transit use. Once a monthly or even annual pass is bought (e.g. for the daily commute to work), the marginal cost of making an additional trip drops to zero. This potentially encourages trip making by public transportation.

Besides regional planning for transit services, the German spatial planning system (see next chapter) prescribes coordination of transportation planning and land-use planning (BMVBS, 2000b; Köhler, 1995; TRB, 2001). Local, regional and state spatial plans have to take transportation plans into account and transportation plans must likewise take spatial plans into account. The German Federal Ministry of Transportation and Urban Development is a good example of integration of city and transportation planning functions. This integration of planning potentially allows for alignment of land use and transportation planning goals and minimizes adverse impacts of transportation externalities. In the U.S., Metropolitan Planning Organizations can serve to link land use and transportation planning, but they are often limited to a relatively weak advisory role with no political power (Orfield, 2002).

The City of Freiburg is an excellent example of integration of all the policies mentioned above. The city transformed its core into a pedestrian zone, improved transit service, reduced parking, introduced parking management, extended its bike network, installed transit priority green lights at traffic signals, and was the first city to introduce a flexible monthly ticket (environmental card) (Banister, 2005; Bratzel, 2000; City of Freiburg, 2006, 2007; Köhler, 1995). As a result Freiburg has experienced an increasing share of bicycling and a slightly decreasing share of trips made by automobile over the last 20 years.

4.6.5 Increasing Traffic Safety, Especially for Walking and Cycling

Both countries have made efforts to increase traffic safety since 1970. Their federal governments have required seat belts, airbags and other so called "*passive safety measures*" in automobiles. However, no matter which indicator of traffic safety is used, in 2004 the possibility of getting injured or killed in traffic was higher in the U.S. than in Germany (IRTAD, 2006). The rate of traffic deaths per 100,000 population was twice as high in the U.S. as in Germany (14.5 vs. 7). Adjusting for the amount of car use in kilometers per capita, the likelihood of getting killed in traffic per one billion kilometers driven was still slightly higher in the U.S. than in Germany (9.4 vs. 8.4).

Both countries have also taken measures to make walking and cycling safer. As for overall traffic risk, however, it is safer to cycle and walk in Germany than in the U.S. Adjusting for kilometers walked and cycled per resident, the likelihood of getting killed in traffic as a pedestrian is five times higher in the U.S. than it is in Germany (1.8 vs. .4 deaths per 16 million kilometers walked), and the likelihood of being killed as a cyclist is twice as high in the U.S. (.8 vs. .4 per 16 million kilometers cycled) (EUROSTAT, 2005-2007; IRTAD, 2006).

Exhibit 4.10 displays the trend in pedestrian and cyclist traffic deaths since 1975. For both modes of transportation, Germany has made more progress in reducing the number of traffic fatalities. Compared to 1975 the number of pedestrians killed in traffic was reduced by 80 percent in Germany and 40 percent in the U.S., while the number of cycling fatalities declined by 60 percent in Germany and 20 percent in the U.S. Clearly, Germany has been more successful in making walking and cycling safer. Policies behind the increases in traffic safety in Germany include (BMVBS, 2006):

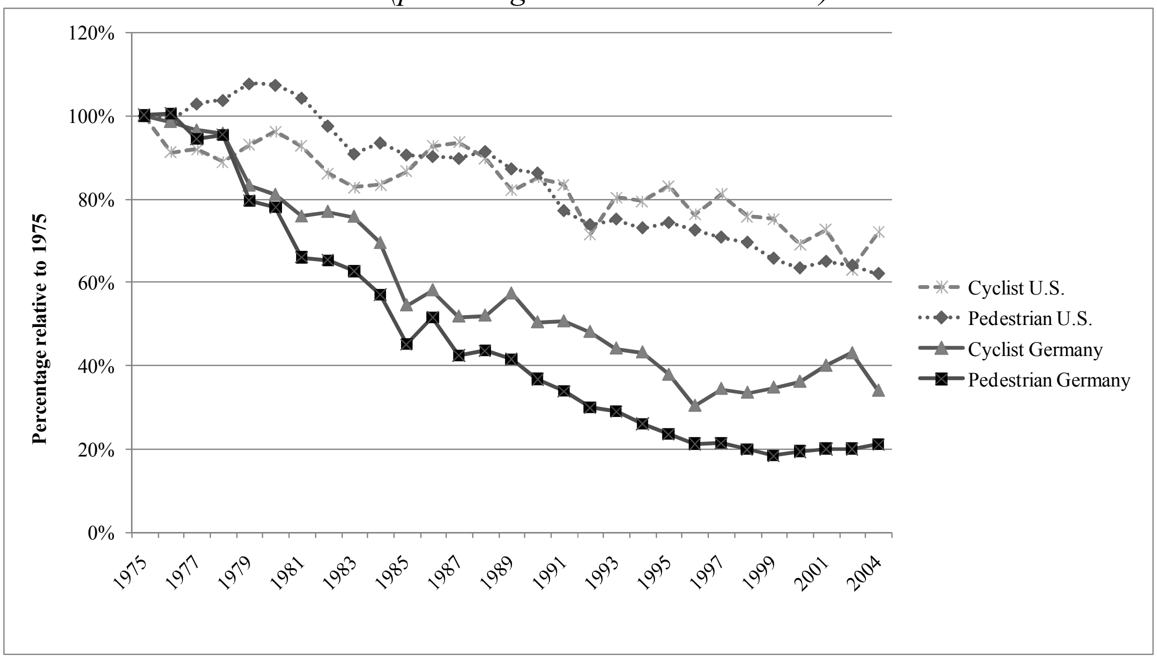
- Traffic education for all traffic participants, including better driver's training, but also educating and training for pedestrians and cyclists about their role and responsibility in traffic
- Public relations campaigns to change "*traffic culture*"
- Enforcement of existing traffic laws, coupled with incentives for good traffic behavior
- Improving safety for vulnerable groups (cyclists, pedestrians, children)

- Reducing speed limits, especially in residential areas and on the Autobahn (many parts of the Autobahn did not have a speed limit at all, but now more and more stretches have a 120km/h limit)
- Improving road infrastructure (including construction of bike lanes and paths, and rerouting of traffic around towns and cities)
- Improving emergency response
- Improving passive safety of cars

Many of these policies were also implemented in the U.S., but, as with traffic calming, not as extensively as in Germany. Neighborhood streets are rarely traffic-calmed, and speeds on highways have been increased in some states, rather than decreased. Student driver training is more extensive in Germany, with a minimum of 20 hours of classes and 20 hours of driving training with a driving coach. There are two final exams, one in writing and one on the road. Both tests have a strong emphasis on respecting the rights of vulnerable groups such as children, the elderly, pedestrians and cyclists. In the U.S., driver's training varies by state, but is not as extensive as in Germany.

A safer environment for non-motorized transportation can help explain higher levels of walking and cycling in Germany. Jacobsen (2003) points out that safety for cyclists and the mode share of cycling might be functionally related. Analyzing time series data for various countries, he found that the more cyclists there are, the safer it is to cycle per kilometer cycled. The causation probably occurs in both directions. The safer it is to cycle, the more people are encouraged to cycle. The more cyclists there are, the higher the awareness of motorists for non-motorized traffic, the more bike training, and the better the infrastructure for walking and cycling. Additionally, with a higher share of trips made on foot or by bike the likelihood that motorists also travel by bicycle or on foot increases. The experience as cyclist and pedestrian potentially influences the level of caution in driving behavior (Pucher & Buehler, 2006, 2008).

Exhibit 4.10 Trend in Pedestrian and Cyclist Fatalities in Germany and the U.S., 1975 - 2004 (percentage relative to 1975 level)



Source: (IRTAD, 2008; Pucher & Dijkstra, 2003)

4.7 Summary: Differences in Transportation Policies in Germany and the U.S.

The literature review had identified four groups of variables accounting for differences in travel behavior: socioeconomics, spatial development patterns, culture, and transportation policies. This chapter traced the differences in and timing of transportation policies shaping the convenience, access and feasibility of all modes of transportation. Policies that govern the automobile, transit, and non-motorized transportation at all levels of government can help explain differences in travel behavior.

The main differences encountered are traditionally higher costs of car ownership and use, and greater supply and subsidies of transit service in Germany. The timing of government policies towards road, transit and non-motorized transportation was also different. Beginning in 1956, all levels of U.S. government focused on road transportation and expanding the interstate and local road networks. Public transportation was neglected until the mid 1960s and has seen a renewed commitment since 1991. Policies on the local or regional level in Germany encourage walking, cycling, and transit use and make car travel less convenient. Since the 1970s, and more so since 1980, most cities have traffic-calmed their residential neighborhoods, installed pedestrian only zones, reduced car parking in city centers, and improved the convenience and attractiveness of public transportation. Regional Transit authorities coordinate transit services, fares, and subsidies region-wide, making public transportation an attractive and viable mode of transportation. While the German federal government subsidized public transportation, efforts towards non-motorized modes of transportation were mainly driven from below. Municipalities expanded their cycling networks and built bike parking at train and transit stations. In the U.S., only a few municipalities implemented traffic-calming schemes, pedestrian only roads, or a bike network. Here, the federal government has appeared to spearhead the efforts to promote non-motorized transportation since the passage of ISTEA in 1991.

Table 4.9 summarizes the main differences between the two countries in transportation policy. Policies affecting the cost and convenience of automobile use include the gasoline tax, parking availability and cost, and car-free zones at city centers. Taxes on the sale of gasoline are about eight times higher in Germany than in the U.S.

As a result, operating costs per kilometer driven of a similar automobile are twice as high in Germany as in the U.S. Parking for automobiles in cities is more restricted and expensive in Germany, and most cities have car-free pedestrian zones in their downtown area, banning cars from driving there. Very few American cities have pedestrian streets and over 95 percent of all car trips in the U.S. end at a destination with free parking.

Another factor influencing convenience and ease of car use is road supply and travel speed. Since WWII, the U.S. federal government has made it a priority to built and finance a viable road network connecting all states and urban areas through the interstate highway system. This system was supplemented through the expansion of state and local roads. The German federal government also invested in roads and expanded the road network, but at a lower level than in the U.S. In 2004 and 2005 there was one kilometer of road per 47 citizens in the U.S., compared to one kilometer of road per 128 citizens in Germany. Clearly, more roads per inhabitant influence travel speed by automobile, which is on average one third higher in the U.S. than in Germany. More roads and faster travel speeds are an incentive to use the automobile versus other modes of transportation.

Not only did the U.S. federal government make road transportation a priority, it also neglected the needs of other modes for a long period. It was only in the 1960s, when most transit companies had already been trapped in a downward spiral of declining transit ridership and service cuts, that subsidies for local transit companies were introduced. Germany has a longer tradition of local and federal subsidies for public transportation. Although road construction is also a priority in Germany, policies and funding have been much more balanced across all modes of transportation compared to the U.S. Today, in both countries, public transportation is heavily subsidized. In 2004, total subsidies (investment and operating) per passenger kilometer of transit use and per transit rider were twice as high in the U.S. as in Germany.[53] This might be related to economies of scale in transit supply and the overall transit availability in Germany compared to the U.S. Germans make an average of 120 transit trips covering 1,120 kilometers per year, compared to 24 trips and 264 kilometers per inhabitant in the U.S. Another explanation may lie in the overall greater availability and attractiveness of transit service in Germany. Transit agencies coordinate timetables, fare structures, and level of service regionally, which makes transit more competitive with other modes of transportation. Additionally, regional monthly transit tickets provide incentives to make more trips on transit in Germany than in the U.S.

Non-motorized modes of transportation are much safer and more attractive in Germany than in the U.S. Federal, state and local governments in the U.S. have long neglected walking and cycling as viable modes of transportation. In Germany, municipalities have made many efforts since the 1970s to make walking and cycling more attractive, by expanding bike networks, creating pedestrian zones, implementing traffic calming of neighborhoods, and imposing restrictions on car travel in cities. While these local policies encourage the use of transit, walking and cycling, they discourage car use by reducing its speed, accessibility, and convenience, and increasing its cost. Therefore the German policy can be described as a carrot and stick approach towards non-automobile transportation.[54] The next chapters investigate the importance of spatial

[53] About \$1.9 per transit trip in Germany, compared to \$4.1 in the US; and \$0.2 per passenger kilometer in Germany, compared to \$0.4 in the U.S. The calculations are based on the following numbers: Twenty-eight billion U.S. dollars for 6.7 billion linked trips and 76 billion passenger miles of transit use in the U.S.; compared to 19 billion U.S. dollars for 9.9 billion linked trips and 92.4 billion passenger miles of transit use (ridership numbers see Chapter 2).
[54] This is more a mix of different policies that were implemeted with different goals and at different times.

development patterns, land-use policies and socioeconomics and demographics as determinants of differences in travel behavior.

Table 4.9 Differences and Similarities in Transportation Policies in the U.S. and Germany

	Differences/Similarities		GERMANY	U.S.
Costs of Owning and Operating an Automobile				
Taxes	Traditionally higher gas taxes in Germany.	*Taxes on Gasoline 2004*	$ 0.8 per liter (using ppp)	$ 0.1 per liter (using ppp)
		Federal Gas Tax 2006	75 U.S. cents per liter	5 U.S. cent per liter
		Federal Gas Tax 1960	12 U.S. cents per liter	1 U.S. cents per liter
		Tax on Vehicle Purchase (2006)	19% Sales Tax	State Sales Taxes (*)
	Operating costs per km dirven are twice as high in Germany.	*Cost per kilometer of driving a similar car (2000/2001) (Ford Mondeo / Taurus).*	$0.47 total cost	*$0.31 total cost*
			$0.31 fixed cost	*$0.24 fixed cost*
			$0.15 operating cost	*$0.07 operating cost*
Fuel Efficiency	Regulation of fuel efficiency (CAFE standards) in the US.	*Fuel efficiency (cars/light rucks) 2004*	8 l per 100 km (29 mpg)	11 l per 100 km (20 mpg)
		Fuel efficiency (cars/light rucks) 1980	10 l per 100 km (23 mpg)	15 l per 100 km (16 mpg)
Parking	More expensive and less parking in Germany.		restrictions on parking in most municipalities	free parking at most destinations of trips
Road Supply and Car Travel Speed				
	More roads per inhabitant and higher car travel speeds in the US.	*Extent of Road Network (in km in 2004/5).*	0.64 million (1)	6.4 million (2)
		Inhabitants per km of road	128	47
		Km of road per sqkm of land area.	1.8	0.7
		Travel Speed of average car trip (2000/2001).	33 km/h	44 km/h
		Passenger km of car and light truck travel per km of road (3)	1.4 million	1.1 million

Continues next page.

Public Transportation				
Funding	*Longer tradtition of government subsidies for transit in Germany. Earlier Federal government funding for transit in Germany.*	*Typical annual subsidy for transit since 2000 (all levels of government). (4)*	$ 19 billion	$ 28 billion
		Average share of government subsidy of transit operating budget since 2000. (5)	35%	60%
Planning	*Regional Integration of transport planning in most German urban areas.*		regional transit organizations integrate fare strucutre, timetables and services	regional cooperation is rare, often no integration of fares or timetables between transit providers
Ticketing and Fare Structure			region wide weekly, monthly, and even annual tickets provide steep discounts for	tickets are rarely integrated across transit providers.
Safety	*Higher likelihood to get killed in traffic in the US than in Germany, especially as pedestrian or cyclist. Better and more training for motorists, pedestrians, and cyclists in Germany.*	*Traffic deaths per 100,000 population*	*7*	*14.5*
		Pedestrian deaths per 16,000,000 km walked	*0.4*	*0.8*
		Cycling deaths per 16,000,000 km cycled	*0.4*	*1.8*

Continues next page.

Non-Motorized Transportation				
Infrastructure	*By far more extensive bike networks, bike parking, bike on transit, traffic calming of neighborhood streets, and pedestrian zones in German cities.*	*Ped/Bike Infrastrucutre*	Sidewalks along virtually all urban roads, most cities have extensive bike networks.	Few cities have bike networks, many subdivisions lack sidewalks.
		Pedestrian Zones	Local efforts in most cities since 1960s/70s.	Only few cities have pedestrian only streets.
		Traffic Calming	Most urban roads in residential areas are traffic calmed.	Only few cities employ traffic calming at a larger scale.
Government Support	*Strong local support for cycling in Germany since the 1960/70s. Federal commitment in the US since 1991.*	*Government Support*	Strong local efforts since 1970s; more recently stronger Federal government support.	Limited local support; Federal Support since ISTEA 1991, but only a fraction of available funds are used by local and state governments.

(*) Ranging from 0-7.25%. Source: Federation of Tax Administrators 2006. http://www.taxadmin.org/fta/rate/tax_stru.html
(1) Source: Verkehr in Zahlen 2004
(2) Source: Highway Statistics 2005 Public Road Length, Table HM 10 (length: 4 million miles)
(3) Sources: Verkehrs in Zahlen 2004 and BTS Table 1-34 "Passenger Miles of Travel". US Passenger kilometers of car and light truck travel for 2004: 7.1 trillion. German Passenger kilomters of car and light truck travel: 872 billion.
(4) Sources: APTA 2006, Roennau 2004
(5) Includes only road based transit in Germany (Source: VDV 2005). Overall government share for investments and operation of transit are about 66% (Roennau 2002, 2004).
(6) US capital funding of transit investments: 29% from own revenues. (APTA 2006, http://www.apta.com/research/stats/fundcap/capfund.cfm).

Sources: (APTA, 2006a; BMVBS, 1991-2007; Federation of Tax Administrators, 2006; FHWA, 1990-2008; Rönnau, 2004; Rönnau et al., 2002; VDV, 2002, 2005, 2006)

5 Land Use and Transportation Planning in the U.S. and Germany

5.1 The Land Use-Transportation Connection

Land-use patterns and travel behavior are closely connected. The growth of cities, their urban form, and their spatial development patterns evolved with their available transportation technology. Arguably, differences in spatial development patterns between the U.S. and Germany can help explain differences in travel between the two countries. More scattered housing, work, shopping, and recreational destinations result in longer trip distances in the U.S., while in Germany more mixed use and denser settlements may be related to shorter trips. All else being equal, longer trips are more likely to be made by automobile, and this may help to explain higher shares of car use in the U.S. This chapter explores trends in spatial development patterns in both countries over time, and describes the spatial planning systems and policies shaping these land-use patterns.

5.2 Current Spatial Development Patterns: Huge Differences

Both countries have experienced increasing suburbanization over the last 50 years, but on very different levels. In a survey of world cities in 1995, Newman and Kenworthy (2002) found that German cities display a population density three times higher than comparable U.S. cities (50 people per hectare in Germany and 15 in the U.S.). Remarkably, they find that even relatively dense U.S. urban areas, such as New York City, San Francisco, or Los Angeles, have population densities about 50 percent lower than the lowest ranking German urban areas (in their survey, the Ruhr-Area and the city of Hamburg). Table 5.1 shows that the population density of Houston was about seven times lower than the density of the Stuttgart urban area, home of the car manufacturers Porsche and Daimler-Chrysler (nine people per hectare compared to 59 people per hectare). In addition, German cities had four times the job density (30 jobs per hectare compared to 7.5 in the U.S.) and more than double the share of jobs in the CBD than American cities (20 percent of all jobs in the urban area, compared to 9.5 percent).

The data might be somewhat misleading, as in contrast to the U.S. data, most of the data for Germany seem to be for cities rather than for entire metropolitan areas (with the notable exception of the Ruhr Area). The authors, however, claim to be comparing metropolitan areas. As mentioned in the literature review, their data have been heavily criticized, but they provide the only comprehensive dataset comparing cities worldwide.

Table 5.1 Population and Workplace Density Indicators of Selected German and U.S. Metropolitan Areas, 1995

City	Population	GDP per Capita ($)	Population Density (person/ha)	Job density (job/ha)	% jobs in CBD
Berlin	3,471,418	23,480	56.0	24.8	20.2
Düsseldorf	571,064	43,745	49.2	35.2	34.3
Frankfurt	653,241	54,571	47.6	38.7	20.5
Hamburg	1,707,901	37,307	38.4	22.3	16.4
Munich	1,324,208	54,692	55.7	32.3	36.3
Ruhr	7,356,500	32,988	36.5	14.6	4.8
Stuttgart	585,604	40,342	58.9	43.3	22.5
German Average	***2,238,562***	***41,018***	***48.9***	***30.2***	***22.1***
Atlanta	2,897,178	31,370	6.4	3.6	9.3
Chicago	7,523,328	32,110	16.8	9.0	10.0
Denver	1,984,578	32,391	15.1	9.0	8.6
Houston	3,918,061	30,680	8.8	4.2	7.2
Los Angeles	9,077,853	28,243	24.1	11.2	4.1
New York	19,227,361	34,395	18.0	9.5	20.7
Phoenix	2,526,113	26,920	10.4	4.3	2.7
San Diego	2,626,714	26,508	14.5	6.6	5.8
San Francisco	3,837,896	37,154	20.5	8.9	13.9
Washington	3,739,330	34,420	14.3	9.2	12.4
US Average	***5,735,841***	***31,419***	***14.9***	***7.6***	***9.5***

Source: (Kenworthy, 2002)

Another study by the Transportation Research Board (TRB) (2001) substantiates the differences found in Newman and Kenworthy´s study. TRB analyzed population densities for central cities, urban areas adjacent to city centers, and the urban area as a whole for ten large American and four large German cities. The TRB report shows that German central cities are slightly denser than their U.S. counterparts (an average of 2,500 people per square kilometer in Germany compared to 2,300 in the U.S.), and that urban areas adjacent to city centers are slightly denser in Germany than in the U.S. (1,050 people per square kilometer in Germany vs. 945 in the U.S.). For the entire urban areas, however, U.S. cities used an average of 50 percent more land area per 1,000 population than German cities (0.6 square kilometers for Germany compared to 0.95 in the U.S.). This indicates that the total developed urban area is denser in Germany than in the U.S., especially areas outside of the city center and the immediate surrounding areas. Overall, TRB finds that differences in land use are less pronounced than in the Newman et al. database.[55] In sum, these studies find that U.S. suburbs are larger than their German counterparts, and that a higher percentage of the metropolitan population lives at low population densities in the U.S.

For the countries as a whole, the average population density over total land area was more than seven times higher in Germany than in the U.S. in 2000 (231 people per square kilometer land area in Germany, compared to 31) (Schulz & Dosch, 2005; Statistische Ämter des Bundes und der Länder, 2007; U.S. Census Bureau, 2006b). Total land area includes large areas of agricultural, forest, and unsettled land. For that reason, a much better measure of settlement density is population density over developed area.

Unfortunately, there are no data available to compare densities over developed areas for the same year. Data from the U.S. Census Bureau cannot be used for developed area, as the U.S. Census Bureau only reports on urbanized land. "*Urbanized land area*" is defined by the Census Bureau as a settlement or census tract with a minimum population density of 1,000 people per square mile (390 people per square kilometer), and therefore ignores low density settlements. In fact, the majority of U.S. households included in the NHTS (National Household Travel Survey) reside in census tracts with less than 1,000 people per square mile of total land area. In contrast, few German

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[55] This might be due to a statistical effect. The definitions of urbanized land area in the TRB study are from the U.S. Census Bureau and the European Union's Atlas of Agglomerations (NEUREC, 1994). The U.S. Census defines urbanized land based on population density (minimum of 1,000 people per square mile). The land area reported therefore excludes low population density areas and might contribute to an overestimation of population density (Details on differences in population density measurements are introduced below).

households in the MiD (Mobility in Germany) are located in municipalities with a population density of less than 1,000 people per square mile of developed land.[56]

In Germany in 2003, there were 1,790 people per square kilometer of developed area, compared to 650 people per square kilometer of developed land in the U.S. in 2001 (Schulze & Dosch, 2005; NRI, 2006). The averages mask considerable variation across states in both countries. In Germany, the states of Mecklenburg-Western Pomerania and Saxony-Anhalt had the lowest population densities in 2003 with 1,000 and 1,127 people per square kilometer of developed area respectively, while city-states like Berlin and Hamburg have population densities of 5,500 and 3,900 people per square kilometer of settled land (DESTATIS, 2005).

The National Resource Inventory (NRI, 2006) provides data on land use in the U.S. since 1982. Its measures of developed land include settlements at all densities. The latest available state level data are from 1997. NRI data for 1997 show that population density over developed, non-federally owned land ranged from 180 and 205 people per square kilometer in Wyoming and Montana to highs between 1,100 and 1,400 people per square kilometer in California, New York, and New Jersey.[57] Remarkably, the densities

[56] At first blush the two different measures -population per census tract land area in the U.S. and population per developed land of a municipality in Germany- do not seem comparable. This is the only available data and it is relatively comparable. Looking closer census tract land area data allow a precise measure of population density around a respondent's home, as they exclude vast areas of undeveloped lands, such as forests, agricultural lands or bodies of water. In Germany population density over developed municipal land, while not definitionally similar to census tract, also excludes forests, farmland, and bodies of water within municipal boundaries. Additionally, German spatial planning law does not allow settlements outside of defined municipal boundaries, by limiting new construction to areas exactly adjacent to already developed land parcels. This ensures that the developed area of a municipality remains relatively compact in Germany (see below for details) even as the municipality grows in size. Even though the level of aggregation in the measurements (census tract and municipality) is different, they both capture similar population densities over settled land area - one by measuring density on the disaggregate level, the other by excluding undeveloped land on the municipal level.
[57] Data for Washington D.C. do not exist in this dataset.

of the U.S. states with the highest population densities over developed land are comparable to the German states with the lowest settlement densities.

Fulton et al. (Fulton, Pendall, Nguyen, & Harrison, 2001) report on population densities over urbanized land for U.S. metropolitan areas based on NRI data for the year 1997. They find that the average population density of metropolitan areas in 1997 was 877 people per square kilometer in the U.S., ranging from 304 people per square kilometer in Ocala (FL) to nearly 2,000 people per square kilometer in the New York City (NY/NJ/CT) and Los Angeles (CA) metropolitan areas.

Population densities for Germany can be computed using the latest German national travel survey, which was enriched with land use data for the statistical analyses later in this dissertation. This data shows that respondents in metropolitan areas of more than three million inhabitants live at average population densities of above 3,400 people per square kilometer. Respondents outside of metropolitan areas live at average densities of more than 1700 people per square kilometer.

Lanzendorf et al. (Lanzendorf, Siedentop, Stein, Wolf, & Hesse, 2005) compare settlement densities for five German agglomerations (Berlin, Erfurt, Essen, Frankfurt, and Hanover). They find that the average density for the five regions was 2,500 people per square kilometer of settlement area in the year 2000. In the central cities of these agglomerations, they find population densities between 3,000 (Hanover) and 5,300 (Berlin) people per square kilometer. Settlement densities in the second cities in these regions range from 1,600 in the Berlin region to 3,000 in the Essen region. The settlement densities of all other municipalities in the regions were between 850 (Berlin) and 1,800 (Frankfurt). Even though these five cities are not statistically representative of

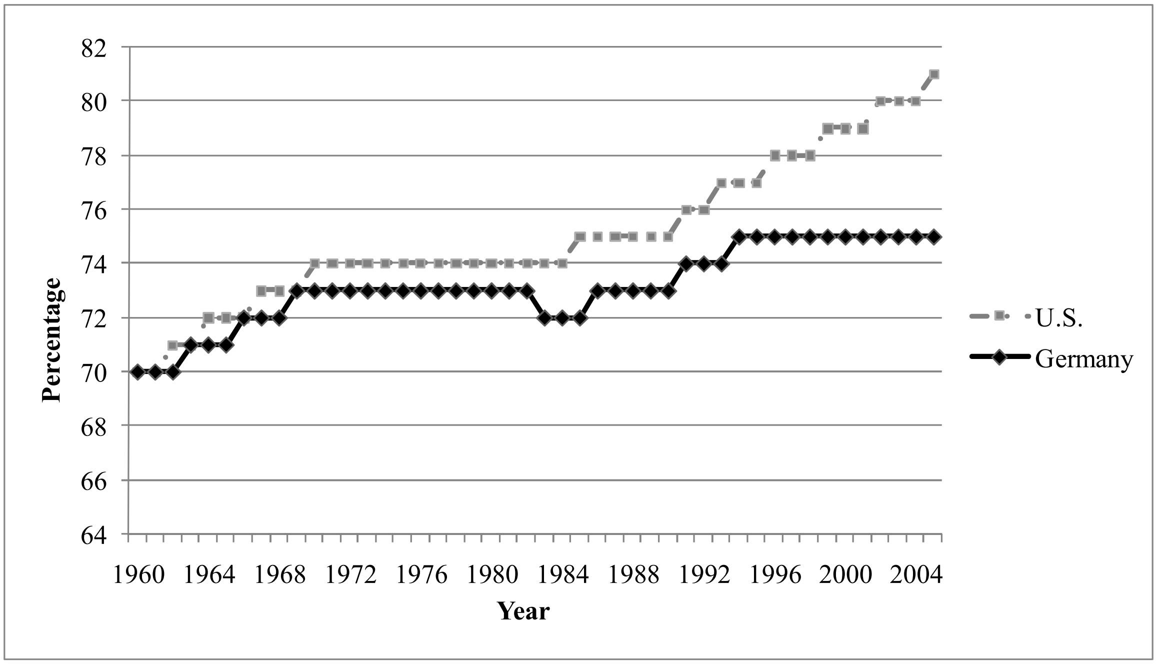
German agglomerations, two points are worth noting. The average densities of the German regions are higher than the highest densities of the U.S. metropolitan areas. Even the densities of suburban municipalities in Germany (e.g. in the Frankfurt region) are as high as the densest metropolitan areas in the U.S.

5.3 Population Growth, Urbanization and Decreasing Settlement Densities over the Last 50 Years

Over the last 50 years, both Germany and the U.S. have experienced increases in the share of their populations living in urban areas.[58] According to the World Bank (World Bank, 2006), in 2005 about 75 percent of the population resided in urban areas in Germany, compared to 81 percent in the U.S. The World Bank data also show that both countries had the same urbanization rate (70 percent) in 1960, and that the share of urbanized population in both countries has grown steadily since then (see Exhibit 5.1). Growth of urban areas in the U.S. has been stronger, especially since German reunification in 1990. Unfortunately, the World Bank does not explain how these data were collected. The definition of urban and non-urban areas might differ between the two countries.

[58] Urban areas are defined as cities and suburbs, in contrast to rural areas.

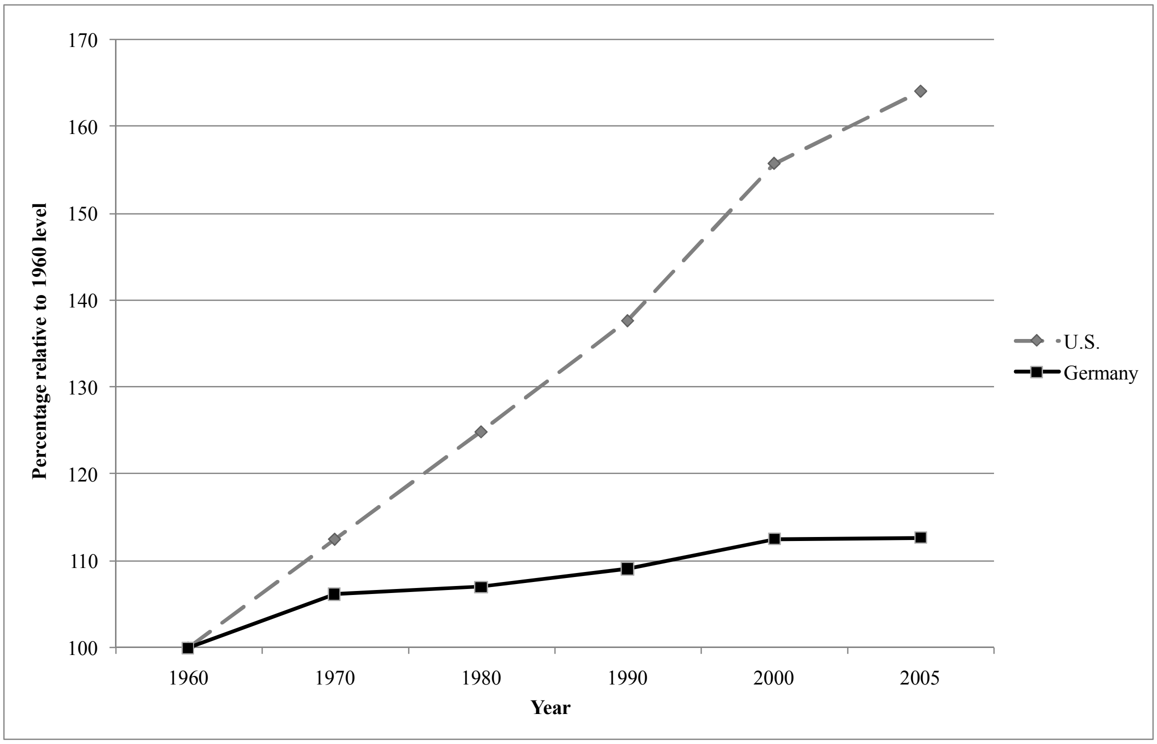
Exhibit 5.1 Trend of Share of Population Living in Urban Areas in Germany and the U.S., 1960 - 2005



Source: (World Bank, 2006)

The percentage of population living in urban areas masks the true magnitude of the growth of urban areas. Exhibit 5.2 shows the population growth in Germany and the U.S. between 1960 and 2005. While the German population only grew by 13 percent, the population of the U.S. grew about six times faster (about 65 percent) over the same period. Faster population growth and urbanization in the U.S. have led to more significant geographical expansion of urban areas than in Germany.

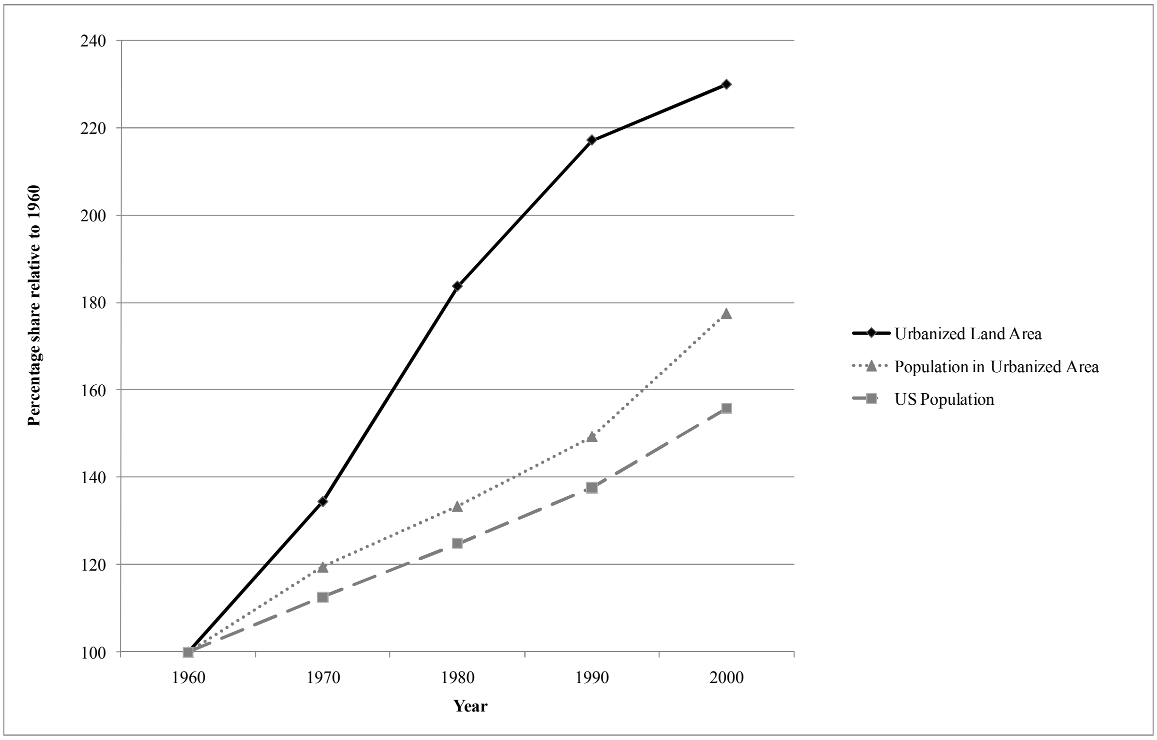
Exhibit 5.2 Population Trends in Germany and the U.S., 1960 to 2000 (percentage relative to 1960 level)*



**Germany data combines East and West Germany from 1960 to 1990*
Sources: (BMVBS, 2003a; U.S. Census Bureau, 2006b; Wendell, 2002)

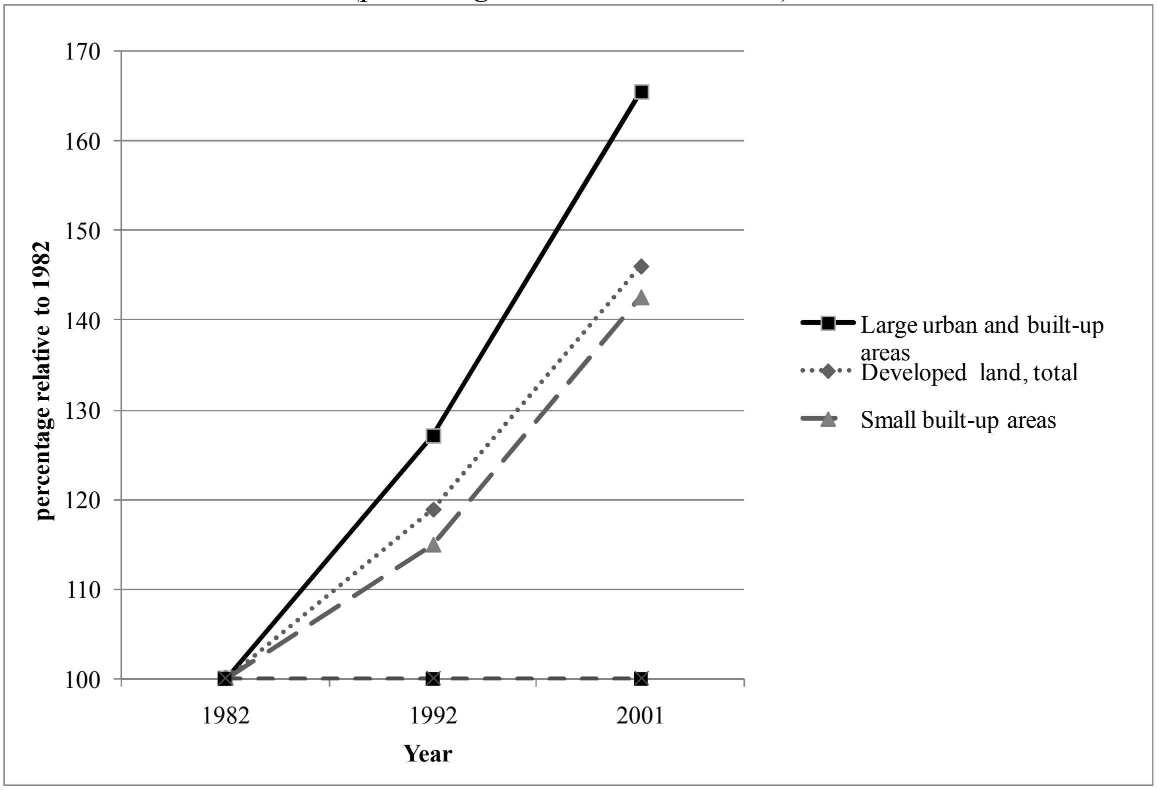
In both countries, the land area used for settlements grew faster than the population. Exhibit 5.3 shows that urbanized land area in the U.S. more than doubled from 1960 to 2000. As explained above, the Census Bureau's definition of urban land excludes settlements with less than 1,000 people per square mile and is therefore not a very precise measure. The National Resource Institute (NRI, 2006) provides data on developed land in the U.S. since 1982. The NRI data show that from 1982 to 2001, developed land area increased by about 45 percent (see Exhibit 5.4), while population grew by only 27 percent (from 1980 to 2000) (U.S. Census Bureau, 2006c).

Exhibit 5.3 Growth of Urbanized Land Areas, Population in Urbanized Area, and Total Population in the U.S.,*
1960 - 2000 (percentage relative to 1960)



** as defined by the U.S. Census Bureau*
Source: U.S. Census Bureau as displayed by (Wendell, 2002)

Exhibit 5.4 Trend in Developed Land in the U.S., 1982 to 2001 (percentage relative to 1982 level)

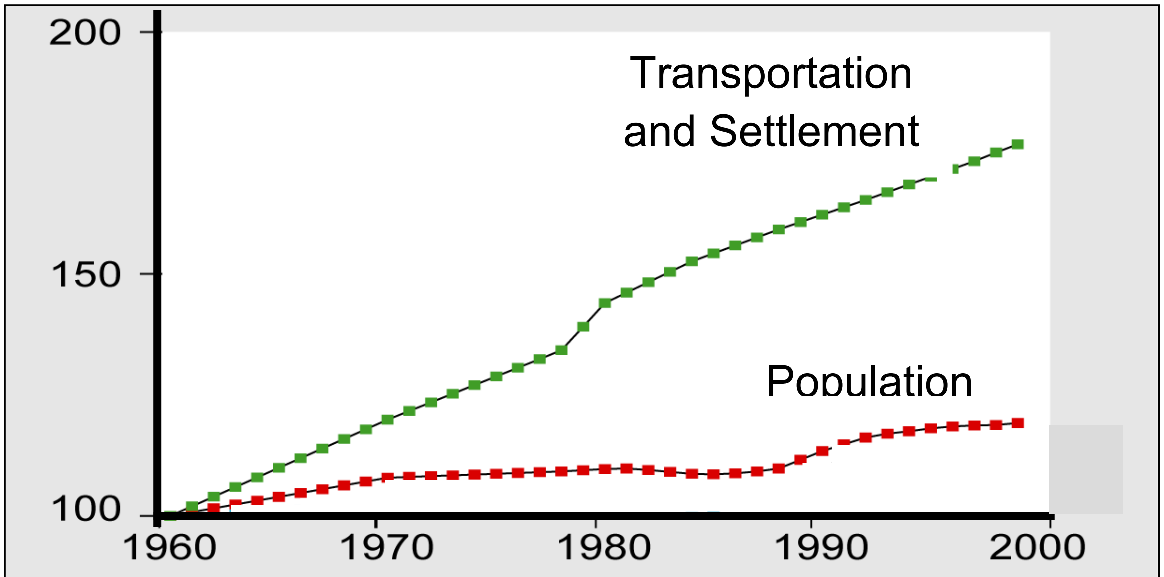


Source: (NRI, 2006)

In West Germany, settlement area also grew much faster than population. Exhibit 5.5 shows that settlement area and land area devoted to transportation uses (henceforth referred to as *transportation area*) grew by more than 75 percent between 1960 and 1997 (Dosch, 2001). The trend data are not entirely comparable, since data collection methods were changed between 1978 and 1980, increasing settled land area by about 10 percent due to a statistical effect (BMVBS, 2005b). More recent data from the German Ministry of Spatial Development divide the growth of developed area into the change in settlement and the change in land area consumed by transportation infrastructure. The data show that transportation area only expanded by about 40 percent, while settlement area grew by more than 100 percent over the last 40 years (1960 – 2000) (BMVBS, 2005b). On average, 1.29 square kilometers of unsettled land were consumed every day for new developed area in Germany from 1970 to 2000.

Since then, this trend has declined to 1.17 square kilometers per day in 2001, about 1.05 square kilometers in 2002, 0.9 square kilometers in 2003, and of 0.7 square kilometers per day in 2004 (Schulz and Dosch, 2005).

Exhibit 5.5 Trend in Settlement Area and Population in West Germany, 1960 – 2000 (as percentage relative to 1960)



Adapted from BBR (BMVBS, 2000a)

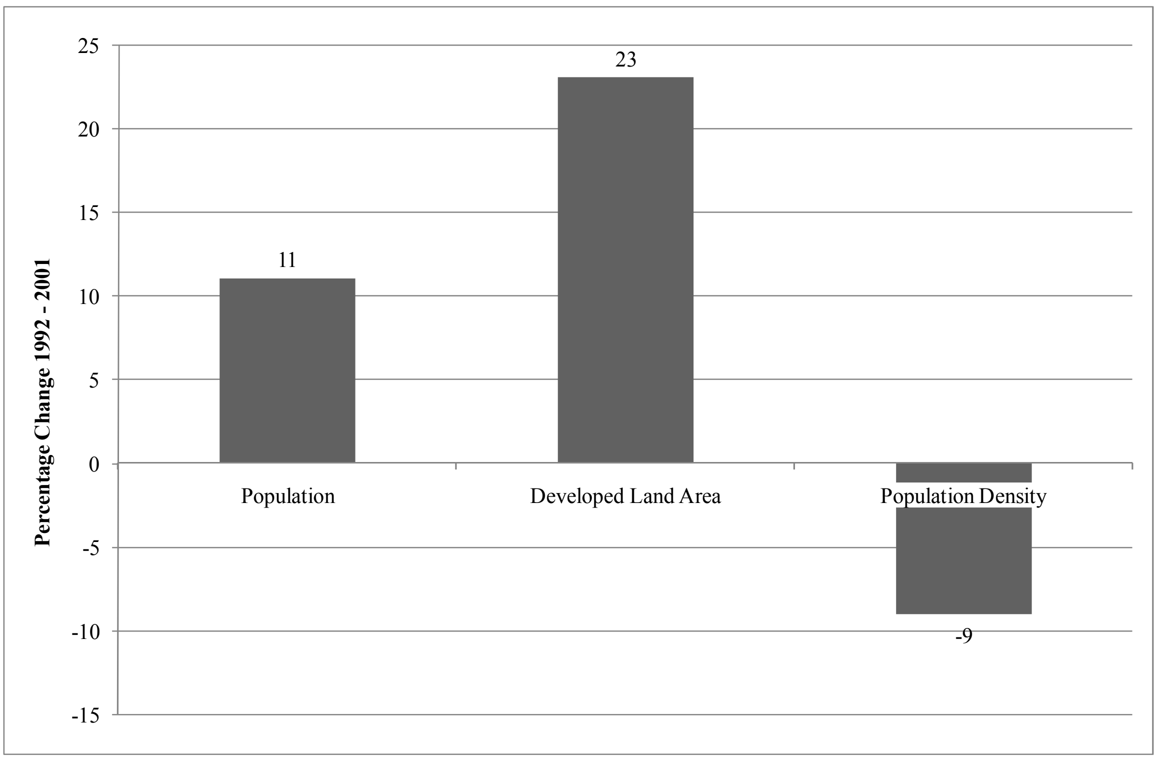
Note: This graph is taken from the German Ministry of Spatial Development. The source data were requested but declared confidential by the ministry.

5.3.1 Recent Trends in Settlement Density

In the U.S., new land area consumed for settlements grew twice as fast as population from 1981 to 2001 (46 percent compared to 23 percent). This resulted in a 16 percent decline in the population density of settled land area. In Germany, the aggregate trend was similar–density declined by 12 percent (GESIS, 2007).

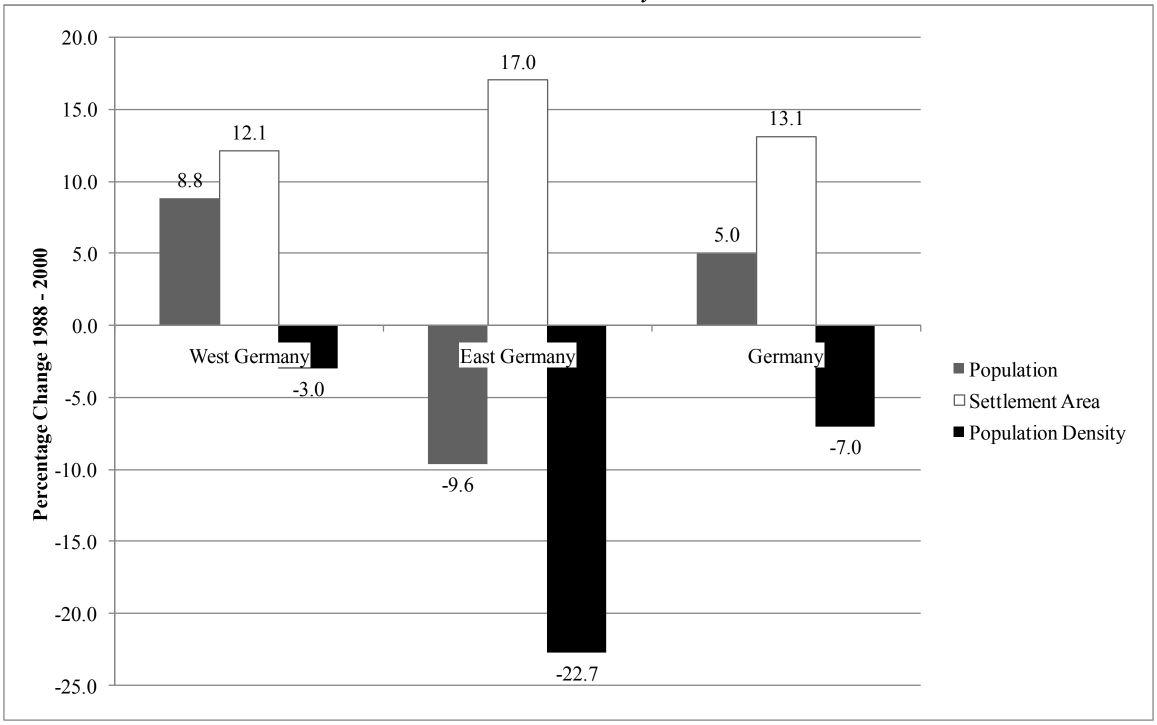
Trends in population density are difficult to trace because of German reunification in 1990. Data for East and West Germany were collected differently. Therefore exhibits 5.6 and 5.7 show trends in population, settled land area, and population density for Germany and the U.S. from 1991 to 2001. The trend is similar as for the data introduced above, but these data are more reliable for Germany as a whole.

Exhibit 5.6 Percentage Change in Population, Developed Land Area, and Population Density in the U.S., 1992 – 2001



Source: (NRI, 2006)

Exhibit 5.7 Percentage Change in Population, Settlement Area, and Population Density in East and West Germany, 1988 – 2000



Source:(UBA, 2003b)

The aggregate data for Germany mask two very different trends in the western and the formerly socialist eastern parts of the country however. In the western part of the country, settlement densities only decreased by three percent from 1988 to 2000, while population density in East Germany declined by close to 23 percent. Settlement area in East Germany increased by 17 percent from 1988-2000, while total population decreased by 10 percent (UBA, 2003b). This is certainly related to housing choices and policies after the fall of socialism in 1990.

Land-use planning during the socialist period forced many people to live in high-density settlements made of prefabricated building blocks (Pucher, 1994; Pucher & Buehler, 2005). After reunification, a property market developed and citizens were free to move where they liked or where they could afford to buy land. Another explanatory factor might be unresolved property ownership for inner city properties in the early 1990s (Stein, 2006). When the GDR was founded, the socialist government seized property from citizens, who very often fled to West Germany. After the fall of socialism, the former owners came back and claimed their property, resulting in many long-lasting court cases between current and former owners, mainly involving inner city properties. This in turn stymied the potential development or reconstruction of buildings, as ownership remained unclear.

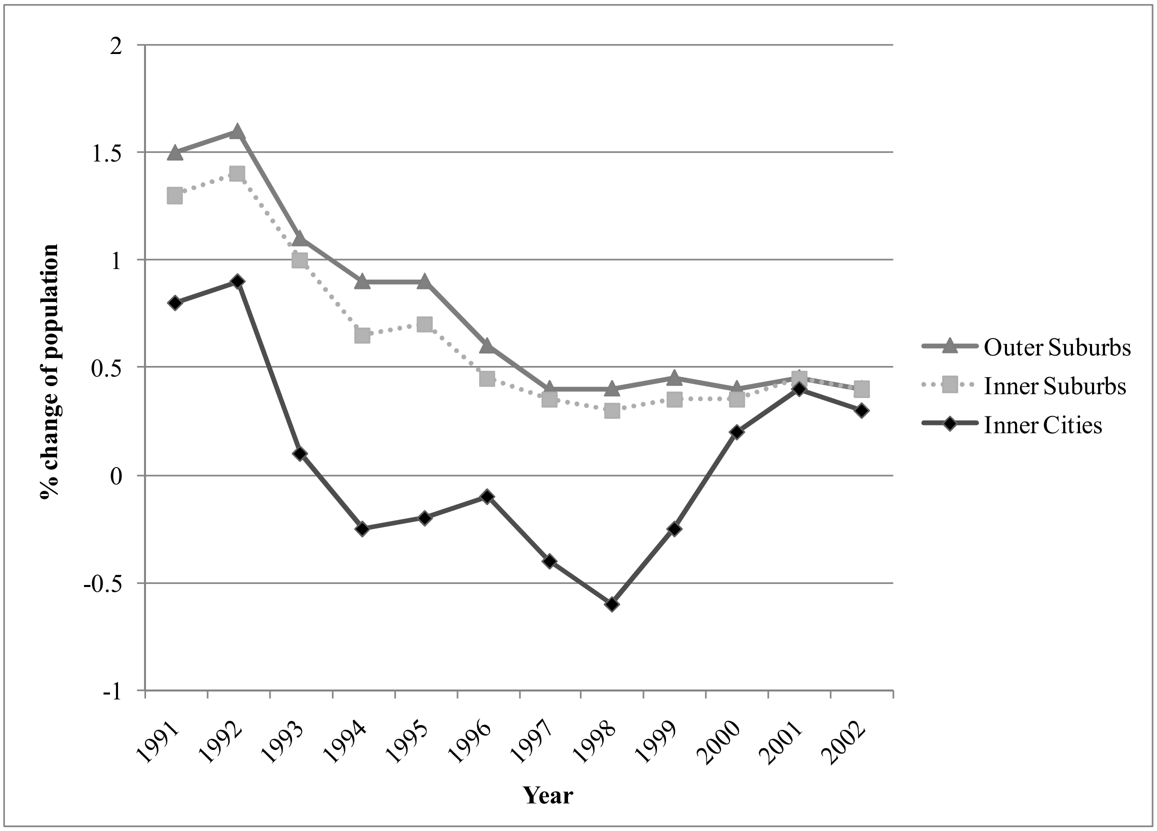
In a study comparing population growth in East and West German cities and suburbs, Lanzendorf et al. (2005) found that the initial boom of suburban development in East Germany slowed down during the early 2000s, with suburbs gaining population at a slower rate and inner city populations holding constant or slightly increasing. Their study also found that West German suburbs gained population during the period from 1990 to 2002, but at a decreasing rate. Similarly, the authors found that West German inner cities lost population from 1993 through 2000, but have begun to gain population since 2000 (Lanzendorf et al., 2005). Overall, the growth of settlement and transportation area in Germany has slowed during the last five years, and it appears that inner cities have witnessed population increases (DIFU, 2004; Mietzsch, 2002; Schulz & Dosch, 2005).

A closer look at population gains and losses in cities and in inner and outer suburbs in East and West Germany verifies this trend. The German Administration for Spatial Development (BBR) defines the inner city and the inner and outer suburb categories according to commuter access to jobs and distance to public services. In contrast to outer suburbs, inner suburbs are located in closer proximity to the city center and have greater accessibility to services and jobs in the central city (BMVBS, 2005).

Exhibits 5.8 and 5.9 below show that inner cities lost population at the expense of inner and outer suburbs during the 1990s. Population growth in lower-density suburban settlements can partially account for the increases in car ownership and use during the 1990s.

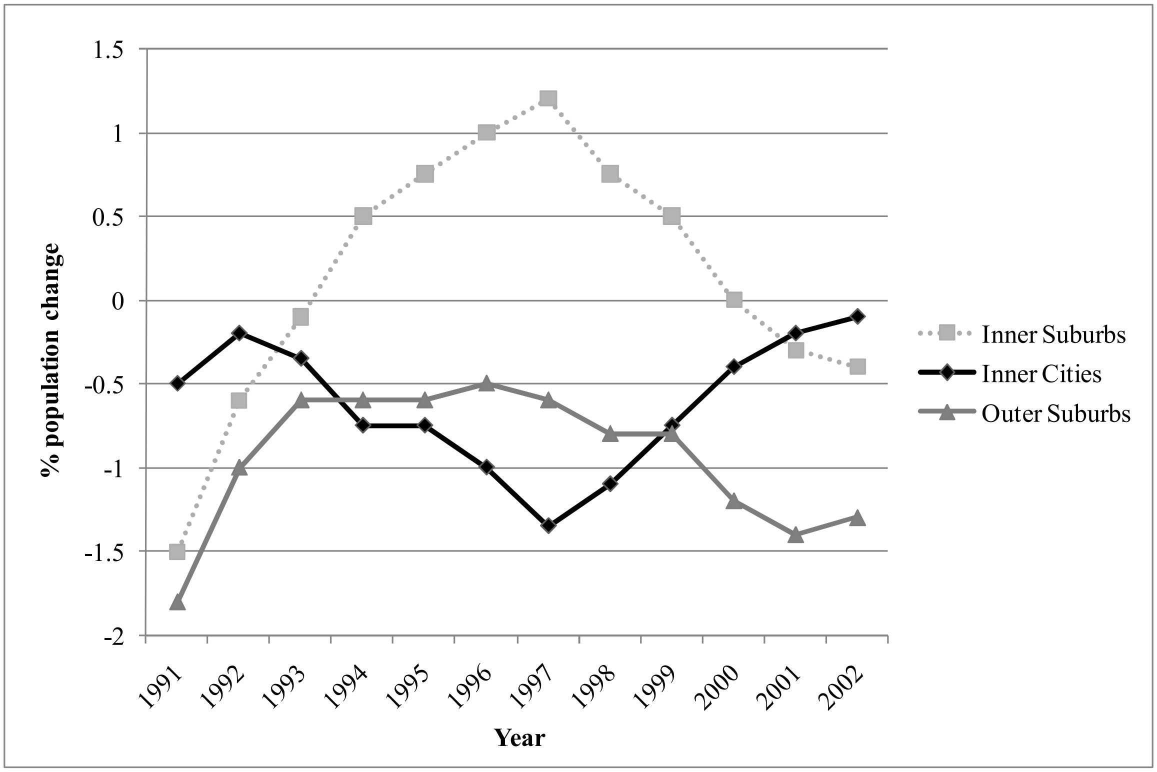
West German suburbs gained population during the period from 1990 to 2002, but at a decreasing rate. West German inner cities lost population from 1993 through 2000, then gained population until 2002. In East Germany, inner cities and outer suburbs both lost population, while inner suburbs grew. The fastest growth for inner suburbs occurred during the early years after reunification and has since subsided. Inner cities managed to slow their population loss between 1997 and 2002 (DIFU, 2004, 2005; Lanzendorf et al., 2005).

Exhibit 5.8 Annual Percentage Change of Population in West German Cities and Inner and Outer Suburbs, 1991-2002



(Source: Adapted from "Mobilitaet im Suburbanen Raum", (Lanzendorf et al., 2005))

Exhibit 5.9 Annual Percentage Change of Population in East German Cities and Inner and Outer Suburbs, 1991 - 2002



(Source: Adapted from "Mobilitaet im Suburbanen Raum", (Lanzendorf et al., 2005))

For the U.S., data as detailed as those in Germany do not exist on the national level, but several reports survey population growth in city centers and urban areas over the last 30 years (e.g. (Birch, 2005; Fulton et al., 2001)). Fulton et al. (2001) surveyed 281 metropolitan areas in the U.S. and found that only 17 metropolitan areas increased their population density from 1982 to 1997. In all other metropolitan areas population density decreased, indicating increasing suburbanization and urban sprawl. There is considerable variation in population density trends within the U.S. The authors show that cities in the Northeast and Midwest added land area at a rate five times higher than population between 1982 and 1997 (about 35 percent growth in land area compared to only seven percent growth in population growth). Metropolitan areas in the Western United States experienced population growth of 32% while land area grew at 49 percent.

Metropolitan areas in the Southern U.S. expanded their settled land by 60 percent and experienced a 22 percent population growth rate over the same period. While cities in the West and South consumed more new land, they also added more population than cities in the Midwest and Northeast.

Lang (2003) further distinguished between the *wet* and *dry sunbelt*[59] based on access to wells and dedicated water supplies for new developments. His theory is that *dry* Western *sunbelt* states have less sprawl, due to limited access to water for new developments. New developments in the *dry* states depend on a water grid, which is not necessary in the *wet sunbelt* states. He finds that the *wet sunbelt* added land area twice as fast as it added population from 1982 to 1997. However, the *dry sunbelt* added land area and population at equal rates during this period.

Birch (2005) surveyed 44 cities and 45 self-defined downtowns[60] and found that downtown populations grew by 10 percent from 1990 to 2000. Seventy percent of the cities surveyed had increasing downtown populations in the 1990s. This was a major change from earlier decades. From 1970 to 1980, more than eight out of ten of the cities surveyed had lost downtown population, as had almost half of the cities between 1980 and 1990. Some cities lost population at a rapid rate. For example, St. Louis and Miami lost 40 percent and 56 percent of their downtown populations respectively in the 1970s. DeMoines and Indianapolis both lost over 50 percent of their downtown population in the 1980s. Overall, from 1970 to 2000 the number of households in downtown areas increased by eight percent, compared to a nearly 100 percent increase in the number of

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[59] The wet sunbelt includes Alabama, Florida, Georgia, North and South Carolina, and Tennesse. The dry sunbelt includes Arizona, California, Colorado, Nevada, New Mexico, and Utha.

[60] Birch contacted local officals to define their downtown and then collected census tract data according to the downtown boundaries obtained.

households in suburban areas. A growth in number of households does not necessarily imply population growth, as average household size has decreased since 1970. In contrast to most German downtowns, which still retain a considerable share of population (BBR 2006), in the first half of the 20th century, many U.S. downtowns had already transformed themselves from residential areas into businesses areas, or even accommodated *undesirable uses*, such as prisons (Birch, 2005).

Fulton et al. (2001) used multivariate regressions to determine differentiating factors between cities with significant sprawl and those with less. Besides differences in the composition of population and geography, they found that cities with greater sprawl had fewer houses connected to the sewage system, depended more strongly on local revenues for education, are more politically fragmented, and have a higher share of privately owned land. These findings hint at the importance of policies and institutions (polity) in shaping urban development patterns. Policies on all levels of government may help explain differences in land use patterns in Germany and the U.S. Section 5.4 will introduce differences in land use regulation and planning in Germany and the U.S.

5.3.2 Suburbanization of Employment and Retail

As was the case with residential suburbanization, the United States also witnessed a stronger suburbanization of employment and retail trade than Germany during the last 60 years. Shin et al. (2006) found that in 1990, the share of employment in the suburbs of 12 large metropolitan areas ranged from 38 percent in Houston to 75 percent in

Philadelphia and Detroit[61]. Suburban employment grew faster than inner city employment in all sectors (manufacturing, wholesale, services, and retail) from 1980 to 1990. Some inner cities, such as Cleveland and Detroit, even saw a decline in employment over that period.[62] More than 65 percent of all retail jobs were outside of central cities in 10 of the 12 cities surveyed in 1990 (exceptions were Houston with 40 percent and NYC with 62 percent). Shin et al. (2006) also found that commuting trips from suburb to suburb and from central city to suburb increased over the same period.

The report *Commuting in America III* (Pisarski, 2006) confirms this trend. The researchers found that in 2000 the suburbs were home to 50 percent of all workers and that 74 percent of jobs in suburbs were held by suburbanites. Furthermore, the report stated that 40 percent of all work trips in the U.S. in 2000 were from suburb to suburb, and nine percent were from city to suburb. Close to 50 percent of all commutes ended in suburbs, while 44 percent of commutes ended in cities (25 percent of these were intra-city commutes, while 19 percent were suburb-to-city commutes) (Pisarski, 2006). The largest share of the increase in commuting by car from 1990 to 2000 was attributed to suburb-to-suburb commutes (64 percent of the total increase), while commutes within or to city centers only accounted for 17 percent of the increase (Pisarski, 2006).

The effect of the suburbanization of employment on commuting distance is still unclear. In contrast to commonly held beliefs, recent research suggests that suburbanization of employment—following earlier residential suburbanization—over the last 20 years shortened commuting distances in the U.S. (e.g. (Crane & Chatman, 2003)). However, these results do not control for increased congestion and the possibility of

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[61] The definitions of center and suburb vary from one metropolitan area to another, and are therefore not fully comparable.
[62] Their population saldo declined over this period.

longer commute times. While commuting times had decreased until the 1990s Gordon et al. (2004) found that commuting times increased from 1990 to 2000.

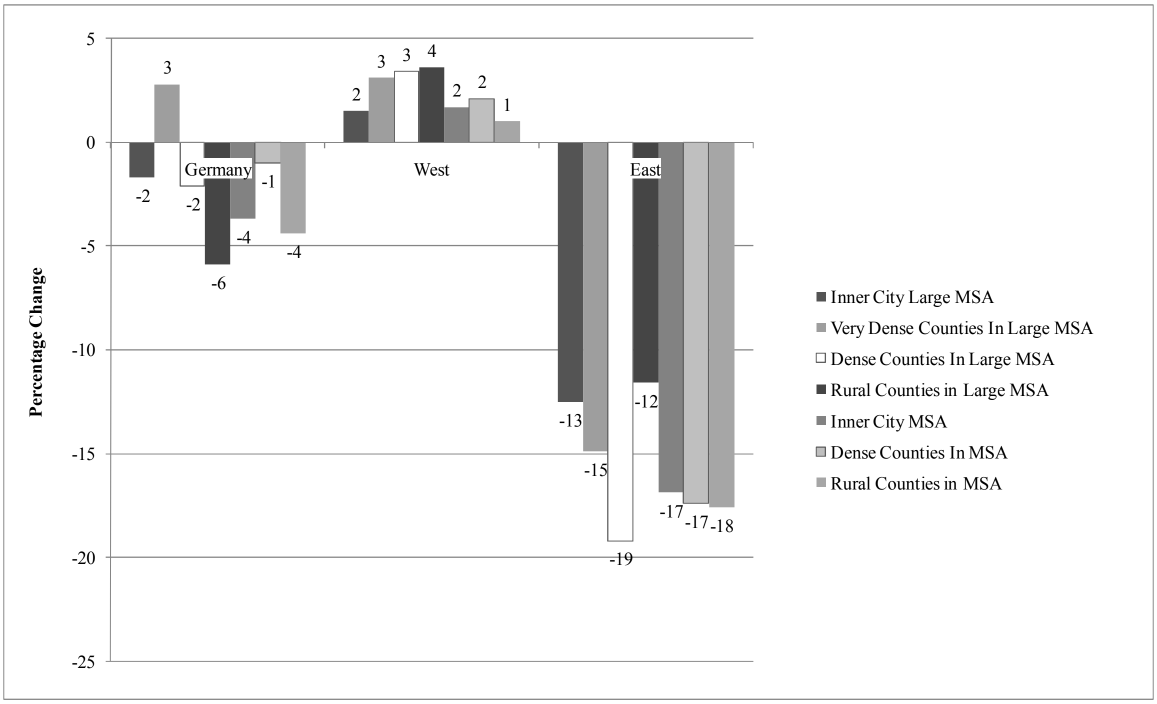
Like U.S. cities, German cities have experienced slower growth and have lost employment and retail stores to suburban locations since 1960 (Karsten & Usbek, 2005; Kulke, 2005). Kulke (2005) observes that during the 1970s and 1980s, the number of large scale supermarkets and retail stores in suburban locations grew rapidly. From 1970 to 1990, the number of grocery stores in Germany decreased from 154,000 to 60,400, while the average square footage per store increased almost six-fold (from 53 to 283 square meters) (Kulke, 2005). Since the early 1980s, the federal government requires special permits for very large supermarkets and retail stores (those with areas exceeding 1,200 square meters) located outside of already developed areas (Kulke, 2005). From 1990 to 2000, the percentage of national retail revenues generated by stores located in city centers in West Germany was stable at slightly under 50 percent. At the same time, the percentage of retail revenues generated outside developed areas increased by seven percent (from 22 to 29 percent). In East Germany the development was more dramatic, with the share of revenue of retail stores in cities declining from 49 percent to 36 percent in the same decade. The share of revenues for retail stores outside of developed areas in East Germany was 40 percent in 2000 (Kulke, 2005). Reasons for this rapid suburbanization of retail might be similar to the residential suburbanization described above. Ownership of inner city properties was not clearly determined, and urban planning was not yet and established practice in the early 1990s. These two factors allowed for the construction of retail stores on undeveloped land outside of settled areas.

Prior to 1990, the jobs that left German cities for suburban locations were primarily industrial. However, over the last 15 years, an increasing number of service sector jobs have followed. Counties (Kreise) adjacent to urban areas, particularly those with good transportation infrastructure, were the main recipients of this new job growth (Karsten & Usbek, 2005). From 1990 to 1999, inner cities agglomerations in West Germany lost about six percent of their jobs. Most of these jobs went to suburban medium and low density areas. Since the mid-1990s, this trend seems to have slowed in West Germany, however.

Exhibit 5.10 shows that in West Germany, inner cities are gaining employment again, while in Germany as a whole, only densely and very densely settled counties adjacent to cities were gaining population. The employment growth rate of inner cities in West Germany was still slower than that of suburban locations. But, inner cities in West Germany were not actually losing employment any longer. As in the case for residential density, employment in East Germany developed very differently than in West Germany for many of the same reasons already mentioned in the section on residential density.

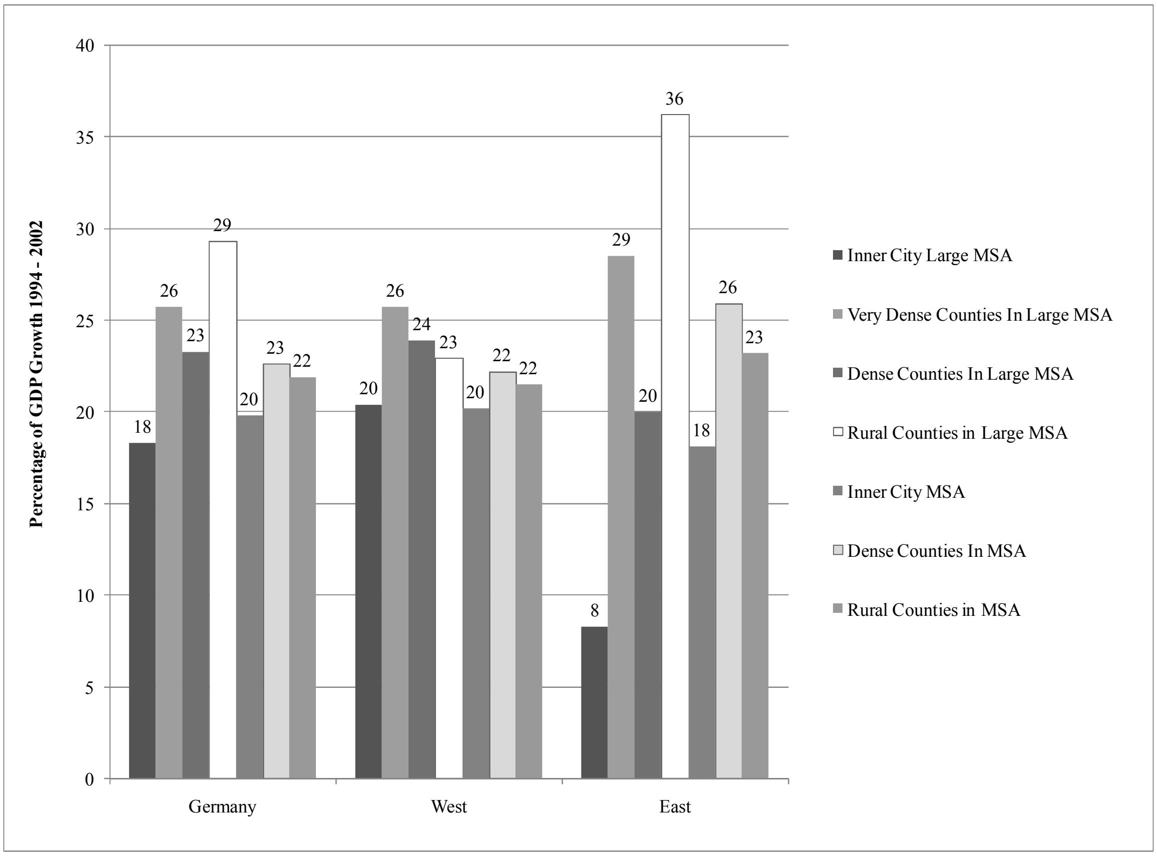
The same trend could be found in the development of real GDP per capita from 1994 to 2002. Inner city GDP grew at a slower rate than GDP in the other counties of the agglomerations, indicating a shift of economic power to suburban areas outside the centers of the agglomerations (Exhibit 5.11).

Exhibit 5.10 Percentage Change of Employment in Counties of German Agglomerations, 1995 – 2002



Source: (INKAR, 2005)

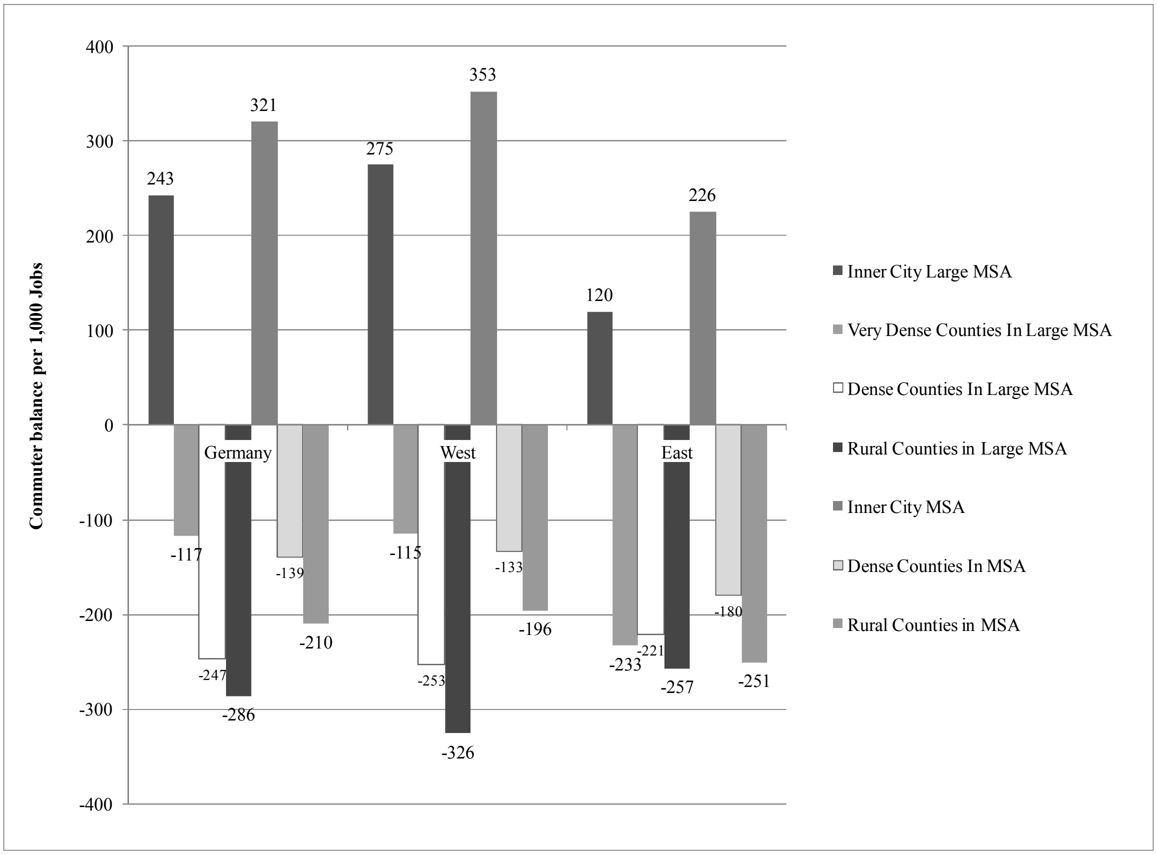
Exhibit 5.11 Percentage Change of Real GDP per Inhabitant in Counties in German Agglomerations, 1994 – 2002



Source: (INKAR, 2005)

In contrast to the U.S., however, inner cities were still the primary location for workplaces in Germany. Exhibit 5.12 shows the ratio of the number of net commuters ("in" commuter minus "out" commuters) to the number of total jobs for counties in German agglomerations. The only areas with more commuters coming in than leaving were city centers. The farther away a county from the city center was, the more "out" commuters there were compared to jobs. Even though commutes to city centers are still dominant, the German Ministry of Spatial Development notes that suburb-to-suburb commutes became more and more common, especially in large agglomeration areas with employment centers in suburban locations (e.g., the Hamburg, Stuttgart or Munich regions) (BMVBS, 2005b).

Exhibit 5.12 "Net Commuters" per 1,000 Jobs in Counties in German Agglomerations*



*(*Commuter Balance (Pendlersaldo) is defined as commuters entering a county minus commuters leaving a county) Source: (INKAR, 2005)*

5.4 Land-Use Planning Systems and Policies[63]

Germany and the U.S. are both federal democracies with a long tradition of local self-government. However, the land-use planning systems in the two countries differ substantially from one another. The main differences lie in: (1) the degree of interaction of different levels of government; (2) the integration of land-use planning with other

[63] The information for section 5.4 is based on an article co-authored with Professor Stephan Schmidt (Cornell University) and was published in the peer-reviewed journal *International Planning Studies* (Schmidt & Buehler, 2007).

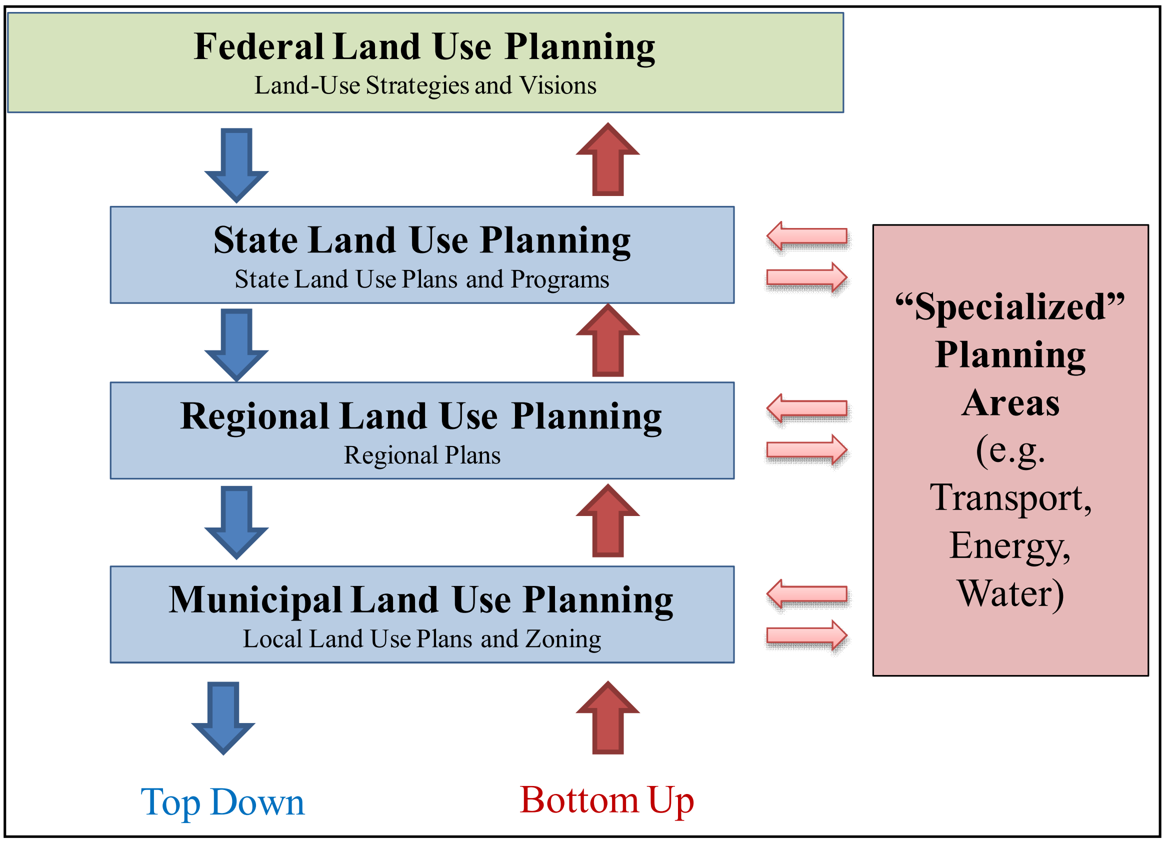
planning sectors (e.g. transportation, energy, or environmental planning); (3) the sources of funding for local governments; and (4) the rights of individuals to develop their property.

5.4.1.1 The Spatial Planning System in Germany: Integration and Consensus

Spatial planning in Germany is mainly the responsibility of the state, regional, and municipal governments. Additionally, the federal government influences spatial planning by publishing guidelines for planning, non-binding "*Federal Spatial Planning Reports*" (Bundesraumordnungsbericht), and laws and regulations pertaining to the planning process. These laws and regulations include, among others, the Federal Planning Law and the Federal Construction Code, which require states, regions, and municipalities to draw-up spatial plans, and define the procedures and tools to be used in planning. During the last decade, the European Union, a supranational government entity, has played an increasing role in planning through its structural funds or requirements for environmental protection.

Exhibit 5.13 depicts the German planning system, which is best described as a "*top-down and bottom-up*" or "*counter current*" process (*Gegenstromverfahren*). There are four levels of spatial planning and all levels of government work together collaboratively. The lower levels of government always have the chance to provide input into higher level plans, but they must then adhere to the goals of these plans once they are set. The lower the level of government, the more precise and detailed the plans. The federal level sets forth broad goals and guidelines; state governments define development corridors and specify goals; regional governments add detail to state plans; and municipalities then decide which uses are going to be built on what parcel of land within their jurisdiction (Newman & Thornley, 1996; Wiegandt, 2004). The system is designed around consensus and mediation among different levels of planning. There is a high degree of informal discussion and opinion exchange prior to and during the planning process. Additionally, specialized areas of planning such as economic development or transportation are included in spatial planning on all levels of government.

Exhibit 5.13 The German Spatial Planning System



Adapted from: (BMVBS, 2000a; Kunzmann, 2001)

The federal government provides guidance and rules for the planning process and broad guidelines for the actual plan. These are set in collaboration with the state ministers for spatial development and the federal minister for spatial development. As in the U.S., the federal government in Germany influences spatial development through investments and fiscal incentives not directly related to spatial planning. These include, among others, funding for transportation infrastructure construction or tax relief programs for new housing construction ("*Eigenheimzulage*")[64] (Bach & Bartholmai, 1993).

The highest level of planning is the state level. All states have planning laws and, together with the sub-state regions, they develop state spatial plans. These plans outline spatial development corridors for future development and define a hierarchy of cities within the state (Kunzmann, 2001). According to this hierarchy of central places, cities provide services, such as universities and hospitals, for citizens in surrounding areas. The German Constitution stipulates that every inhabitant has the right to similar living conditions and access to services, no matter where they live (Fuerst & Scholles, 2003). The network of central places ensures similar levels of access to government services and employment centers. State and federal governments distribute subsidies to cities to provide these services and to provide similar living conditions. The subsidies vary according to each city's rank in the city hierarchy and according to the level of services they are obligated to provide.

State spatial plans are also coordinated with plans for other *specialized* areas of planning (Fachplanung), such as economic development, transportation, and environmental preservation. For example, the development corridors defined in the state spatial plan are mainly along major transportation corridors (Spitzer, 1995). Regional planning bodies have access to the planning process or can comment on the plans before they are voted into law by the state assembly.

[64] Similar to the U.S., the German government subsidized (until 2007) home buyers and builders for eight years with tax breaks. In contrast to the U.S. however, the German subsidies were limited in time (8 years), were only granted once in a life time, and were only available up to a certain annual income (Bach, 1995).

The next lower level of planning is the regional level. Regional plans have to adhere to the goals set forth in the state plans. Generally, the state plan contains: (1) goals that must be pursued (*Ziele der Raumplanung*) and (2) recommendations that can be tailored to local circumstances (*Grundsaetze der Raumordnung*) (BMVBS, 1993). The regions assemble regional plans in coordination with municipalities. These regional plans include input from specialized planning areas and officials from neighboring regions. In general, regional assemblies have the authority to ratify or reject regional plans. These assemblies are made up of representatives from the counties comprising the region. Regional planners also comment on municipal land use plans and verify that they are consistent with regional goals (Fuerst & Scholles, 2003; Herzberg, 2006).

Municipal governments draw up the actual land-use plans and decide where different uses are to be built. Local plans are restricted by the regional and state plans and must be in compliance with federal laws. There are two kinds of local land-use plans: the preparatory *Flaechennutzungsplan*, compiled for the entire developed area of the settlement; and the *Bebauungsplan*, specifying developments for subdivisions and specific plots of land. In contrast to the U.S., in Germany land not immediately adjacent to already settled areas (*Aussenbereich*) is generally off limits for development, though some exceptions are made on a case by case basis (BMVBS, 1993; Schneider, 2006). Municipal land-use plans must be approved by the county, and municipalities must provide justification for development of land that is not contiguous to developed areas. The regional planning body supplies the county with an evaluation of the specific local land-use plan, but the county has the final say on accepting or rejecting the municipal plan. As at all levels of government, local land-use plans also incorporate specialized planning areas, such as transportation, energy or sewage.

Land owners, unlike their U.S. counterparts, do not have the right to develop their property until a *Bebauungsplan* has been established. This is especially true for land areas not adjacent to current development, as mentioned above. Even in the case of private land, the municipality must convince higher levels of government that development is beneficial and that it cannot occur elsewhere. Higher levels of government can then weigh the arguments for and against development and render a decision.

5.4.2 Land-Use Planning in the United States

The most striking difference between the U.S. and Germany is the lack of a coherent spatial planning system integrating local, regional, state and federal governments in the United States. In fact, as Kayden (2001) remarks, the term "*spatial planning*" —commonly used in Europe—is not part of legal or professional vocabulary in the U.S. The federal government is not directly involved in land-use planning. Indirect influences include the "*takings clause*" (defining property rights) in the U.S. Constitution (5^{th} and 14^{th} Amendments) and federal laws, rules and programs that have an indirect spatial effect, such as those related to environmental protection, housing, economic development, public land use, and transportation (Bruegmann, 2005).

Planning in the U.S. has traditionally been organized along sectoral lines (e.g., transportation, economic development, and housing), rather than using a more comprehensive approach, as is commonplace in Germany. In the U.S. there are many federal policies and subsidies that have had a large impact on spatial development since

World War II, but which cannot be considered federal land-use planning (Bruegmann, 2005; Squires, 2002; Wickersham, 2006). These policies include: (1) federal funding for the construction of the Interstate Highway System; (2) federally backed mortgages for housing construction; (3) housing construction credits for WWII veterans; and (4) federal subsidies for water and sewage systems in emerging communities. An attempt to pass a Federal Land-use policy Act, which would have encouraged sharing of information between local, state and federal governments, was rejected in the 1970s (Kayden, 2001).

By constitutional provisions spatial planning in the U.S. falls in the purview of the states. In addition, during the 1920s state governments devolved the right to zone to municipalities as part of their police power (so called zoning enabling legislation). Growth management policies at the state level have become more common, but there is no uniformity of approach (Bollens, 1992, 1993). Some studies have attempted to classify state planning in the U.S. Nelson and Duncan (1995) find strong state legislation in Hawaii, while Wilson and Patterson (2002) and APA (2002) classify state planning in New Jersey as "*progressive*" and in North Dakota as "*dormant*". In contrast to Germany, most U.S. states do not produce state level spatial plans, but limit themselves to "*non-spatial*" regulations. New Jersey is an exception, as it has established a "*State Plan*" that requires approval from all municipalities. APA (2002) found that 37 U.S. states were developing or had already implemented statewide land-use planning approaches and that many states were moving towards a more comprehensive approach to spatial planning.

State planning first emerged in the 1960s and 1970s in the U.S. mainly as a response to environmental concerns. It was believed that municipalities alone could not efficiently and effectively control the externalities resulting from population growth, and that growth therefore had to be regulated and limited. This movement is often referred to as "*The Quiet Revolution*", after a book written by Bosselman and Callies in 1971 (Bosselman & Callies, 1971). A second generation of state planning emerged in the 1980s that was less rigid in its regulatory approach and more accommodating to economic growth. In the 1990s, the focus shifted towards limiting urban sprawl, protecting natural resources, and facilitating historical preservation, infrastructure management and urban redevelopment. Compared to Germany, these state policies are relatively limited and not as comprehensive in approach.

Regional planning has a long tradition in the U.S. In the 1920s, regional plan associations in large U.S. cities (e.g. New York, Los Angeles, and Chicago) began planning for the future of their metropolitan areas. These planning bodies were not integrated into a formal planning hierarchy incorporating state and local governments but rather grew out of the utopian traditions of early planners, such as Lewis Mumford. Comprised of prominent citizens, these associations were able to influence regional development, albeit not as part of any formal government process.

Every U.S. city with more than 50,000 inhabitants is required to have a Metropolitan Planning Association (MPOs). Created by federal transportation legislation in the 1970s, these region-wide planning associations were later reduced to data clearinghouses, as they had no executive authority (Weiner, 1996). With ISTEA legislation in the early 1990s, MPOs received independent funding streams and greater authority design and implement regional plans (Orfield, 2002). However, compared to Germany's regional planning organizations, the authority and role of the MPOs remain limited.

Most planning power remains on the municipal level in the U.S. As noted above, local planning in the U.S. has its roots in the 1920s and emerged from Euclidean Zoning. The basic idea was to ensure public safety and sanitary conditions by separating different land uses (e.g. residential, commercial, industrial) from each other. Zoning has generally become more flexible and comprehensive over time, but in many places Euclidean Zoning is still very much alive. Zoning, with its separation of uses, maximum residential density and minimum parking requirements, contributed to lower settlement densities and longer trip distances (Wickersham, 2006).

Moreover, local governments subsidized low density settlements by building local roads and utility (water, sewage, electricity) connections free of charge to the business or home owner (Burchell, Lowenstein, Dolphin, & Gully, 2002). Pendall, Puentes, and Martin (Pendall, Puentes, & Martin, 2006) found that there is a wide range of approaches to local land-use regulation in the U.S. today, ranging from "*traditional*" to "*reform*" (Schmidt and Buehler 2007). In contrast to Germany, there is no federal requirement for municipalities to plan or to zone. While some municipalities have comprehensive plans and corresponding zoning, other municipalities, usually smaller or more rural ones, do not have any planning or zoning at all.

5.4.3 Mixed-Use Development and Separation of Uses

In both countries, the separation of residential, industrial, and commercial land uses through single-use zoning has been the preferred mode of development since the 1950s (Hirt, 2008; Levine, 2006; Levine, Aseem, & Gwo-Wei, 2005; Wiegandt, 2004). Even though Germany still has many more mixed-use developments than the U.S., planners in both countries for a long time favored the separation of uses over a mixture.

The arguments for this kind of local planning were the same in both countries: separation of uses assures safety and security, and minimizes the nuisance caused by the spillover of the external effects of one use (e.g. industrial) onto another (e.g. residential) in mixed-use developments.

In both countries, the negative effects of single-use zoning, low density settlements, and urban sprawl have become apparent over recent decades (Wiedgandt, 2004; Levine, 2006). Like the U.S., Germany has no state or federal laws requiring mixed use zoning. Local municipalities have a great deal of flexibility in deciding how to zone and use their land, but are of course constrained by the planning system described above. For example, land outside of developed areas is generally off limits for development. Additionally, the federal building code, which has no U.S. counterpart, calls for sustainable development and the creation of healthy environments for humans, but offers no guidance on how to achieve these goals.

Decisions in Germany are made locally, based on a careful weighing of private and public interests, as prescribed by federal and state legislation. According to Wiegandt (2004), the influence of single-use zoning on local planning codes posed obstacles to mixed use in the past, but this has changed. Germany has "*witnessed a turnaround in many goals of urban planning – today high density and functional mixture are strategic goals of urban development.*" (Wiegandt 2004). A review of local zoning laws and regulations by Hirt (2008) showed that definitions of single use vary considerably in Germany and the U.S. German single-use residential zones for example allow doctor's offices, hostels, and multistory apartment buildings. In the U.S. these uses are often deemed incompatible with residential single family zones.

As discussed earlier in this chapter, in the U.S. single-use zoning regulation is still commonplace in most municipalities (Levine, 2006). Some municipalities and states experiment with urban growth boundaries, transit oriented developments, and smart growth strategies (Boarnet, 2001). The effectiveness and results of these efforts are still contested. While Ewing (1997), Cervero (2003), Burchell et al. (1998), and Levine (2006) allege that mix of uses and higher density developments reduce overall travel, other authors are more reluctant to accept this conclusion. Handy (1996 cited in Boarnet, 2001), for example, found that mixed-use development potentially increases the number of trips made per day. Reviewing dozens of studies, Ewing and Cervero (2001) found that the socioeconomic characteristics of the trip maker or household are more important in explaining travel behavior than the built environment. The mix of uses increases accessibility to destinations and increases the number of trips by foot and bike. It is empirically unclear, however, if these trips are substituting for car trips or if they are additional trips (Shay & Khattak, 2007).

Miller and Badoe (2000) summarize multivariate statistical studies analyzing the influence of urban form, socioeconomics, and transit supply on travel behavior. The studies analyzed produce a mixed picture, with some concluding that higher densities and mixed uses result in lower automobile ownership levels and less car use, and others finding only a weak connection at best. They point out that density, mix of use, regional accessibility, transit supply, and socioeconomic factors together play a role in shaping travel behavior.

5.4.4 Local Public Finance and Splintering of Local Governments

Unlike the German system, the U.S. has no financing mechanism aimed at equalizing financial power of different municipalities and regions.[65] Federal government investments, such as defense expenditures, have a large impact on municipalities, but are not geared toward equalizing local or regional economic disparities (Downs, 1999). Compared to their German counterparts, U.S. municipalities are more reliant on the private sector and local property taxes as the main contributors to their own-source income. The importance of the private sector often reduces the role of municipal planning to approval of plans already drawn up by private developers and planners (TRB, 2001).

Most large tax bases in Germany, such as the income tax, are shared between local, state and federal governments. These taxes are collected by the federal government and are then distributed proportionally across states and municipalities, according to their share of population. As mentioned above, in many instances municipalities also receive subsidies for providing services, according to their function in the system of cities (BMVBS, 2000). Municipalities in declining regions receive additional funding.

Municipalities in the U.S. rely heavily on local property taxes for their revenue. In 2002, U.S. municipalities received 59 percent of their revenues from own sources and close to 60 percent of these own source revenues came from property taxes. Intergovernmental transfers constituted about 25 percent of municipal revenues in the U.S.[66], compared to 41 percent in Germany (DESTATIS, 2006; U.S. Census Bureau,

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[65] Some local exceptions exists: e.g. tax base sharing of growth of business taxes in Minneapolis-St.Paul.
[66] These percentages differ depending on the kind of local government. The percentages given here are for municipalities. For all kinds of local government (including school districts) the percentages are as follows: 55 percent of revenue is revenu from own sources; 61 percent of own revenus comes from

2002). Property taxes only comprised nine percent of municipal revenues in Germany in 2005. Local business taxes play a larger role in Germany than in the U.S. and can lead to competition among municipalities (Schneider, 2006).

In contrast to the U.S., German municipalities also perform certain functions for higher levels of government and are reimbursed for these services. Municipalities issue passport or building permits on behalf of the federal government and receive compensation for performing these services locally (BMVBS, 2000). In the U.S., municipalities also receive matching funds for local projects from states and the federal government. In general, however, greater reliance on locally generated funds and on the private sector in the U.S. results in more pronounced competition among municipalities for development than is found Germany.[67] This could potentially impede regional cooperation.

Regional coordination in the U.S. is further hindered by the sheer number of local governments. However, the main difference between Germany and the U.S. does not lie in the number of municipalities or counties per inhabitant. As of 2002, there were 14 municipal and county governments per 100,000 population in the U.S., compared to 18 in Germany (DESTATIS, 2006; U.S. Census Bureau, 2002). The major difference is found in special purpose governments such as school districts. The number of special purpose governments nearly tripled in the U.S. from 1952 to 2002 (U.S. Census Bureau, 2002). Since the 1990s, there have been more special purpose governments in the U.S. than municipalities and counties (Blatter, 2006). In Germany, many local services, such as schools are provided by the states or by counties.

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property taxes; and 37 percent are intergovernmental transfers from state and Federal governments (U.S. Census Bureau 2002, http://www.census.gov/govs/estimate/0200ussl_1.html)

[67] This does not mean that there is no competition in Germany, but *less,* compared to the US.

5.5 Summary of Differences in Spatial Development Patterns and Land-Use Policies and Planning

Germany and the U.S. have witnessed similar trends in spatial development patterns over the last 50 years. In both countries, the percentage of the population living in rural areas shrank to about 19 – 25 percent. Urban areas experienced suburbanization and declining settlement densities. In both countries, the settlement area consumed by new developments grew faster than the population. Over the last decade, both countries have once again witnessed some population growth in city centers.[68] These similar developments occurred at different levels of settlement density, however, and major differences still exist (Table 5.2).

On average the density of German settlements is three times greater than that of their U.S. counterparts. The settlement densities of inner and outer suburbs in Germany are particularly high compared to the U.S. Thus dissimilar suburban densities seem to be the driver in different metropolitan area population density between the two countries.

German cities play an important role as residential, employment and retail centers. Cities there provide access to services and infrastructure within a country-wide system of central places. Some American cities have become either partly business centers or empty shells with high crime rates, unemployment, social problems, and segregated poor populations. There are of course notable exceptions, such as New York City and Chicago. German cities have higher shares of national retail trade, employment, and population than cities in the U.S. In Germany, commuting patterns are more oriented

[68] During the last decade, the trend in settlement density in East and West Germany occured at two levels. Settlement densities in West Germany only declined by three percent from 1988 to 2000, while East German settlements grew spatially (17 percent), even though population declined (-9 percent). More recent data indicate a deceleration of suburbanization in both parts of the country.

towards the city center and there is less suburb-to-suburb commuting. Germany's transit systems are crucial in supporting denser developments along transit corridors and more city-centered commuting patterns.

Another important difference between the two countries lies in the land-use planning systems. Over the last decade, several U.S. states have launched new initiatives to introduce spatial planning at the state level. Moreover, since the early 1990s, MPOs have gained more importance in integrating transportation with land-use planning at the metropolitan level. It is still unclear if state-level planning and the newly gained power of the MPOs will be able to slow urban sprawl. Currently, there is very little evidence to support this claim. Competition for property taxes between municipalities in the U.S. makes statewide or even region-wide collaboration for curtailing sprawl very difficult. A tradition of home rule and local decision making also works against the development of region-wide or statewide land-use controls. Spatial planning in Germany is much more stringent and integrated than in the U.S. Formal links and channels of communication exist between the different levels of government and between land-use planning and other specialized planning sectors (such as transportation).

Finally, there are major differences in the right to develop property. In Germany, development of land outside of settlement areas is prohibited except where it is specifically permitted by local, regional and state planners. The property must provide the planning agencies with justification for proposed development. In the U.S. the situation is reversed: the property owner has the right to develop his or her property, and the government must justify any decision to obstruct development.

Table 5.2 Differences and Similarities in Spatial Development Patterns and land-use planning in Germany and the U.S.

	Germany		**U.S.**
Share of "urbanized (non-rural) population"	75%		81%
Population per sqkm of total land area in 2000	231		31
Population per sqkm of developed land (2003/2001)	1,800		650
Population per sqkm of developed land in States (2005/ 1997)	From 1,000 (Mecklenburg) to 5,500 (Berlin)		From 200 (Wyoming) to 1,400 (New York and California)
Population per sqkm of developed land in MSA (2000/1997)	2,515		From 304 (Ocala, FL) to 2,000 (NYC and L.A.)
Average Share of Metropolitan Jobs in CBD (1995)	22.50%		9.50%
Population growth 1960 - 2000	12%		65%
Growth population 1990 - 2000	Germany	5%	11%
	East Germany	-10%	Metropolitan Areas in the Midwest and Northeast +7%
	West Germany	+9%	Metropolitan Areas in the West +32%
Growth urbanized land 1990 - 2000	Germany	13%	23%
	East Germany	-17%	Metropolitan Areas in the Midwest and Northeast +35%
	West Germany	+12%	Metropolitan Areas in the West +49%
Change in Population Density 1990 - 2000	Germany	-7%	-9%
	East Germany	-22%	Metropolitan Areas in the Midwest and Northeast +35%
	West Germany	-3%	Metropolitan Areas in the West -21%
Employment location and commuting patterns	Inner cities are major employment centers, most commutes are suburb to city or city to city.		High share of jobs, sometimes even the majority in suburban locations. Commutes to suburbs increased the fastest between 1990 and 2000. Fifty percent of all commutes end in suburbs and 75% of jobs in suburbs are held by suburbanites.
Planning Systems	"Top-down/bottom-up process", formal links to sectoral planning (e.g. transport), hierarchical system of central places		Most planning on municipal level, few established links between land use and sectoral planning
Local finance	Taxes shared between different levels of government, subsidies from higher levels of government, local competition exists, but is mitigated through the planning process and government subsidies		Reliance on property taxes, comparatively more local competition in the US. Significant federal and state subsidies exist however for specific functions (e.g. housing, environmental protection, and transport).

6 Datasets and General Modeling Approach

This chapter is grouped into four main sections. The first part introduces and compares two national travel surveys that served as basis for the multivariate analyses. In the second part data merging and manipulation for both surveys are described. Third, the general modeling strategy for the multivariate analyses is laid out. Finally, hypothesis for the influence of explanatory variables on travel behavior are stated.

Subsequent chapters will include analyses with four different dependent variables measuring travel behavior: 1) trip frequency per day, 2) daily travel distance, 3) daily travel distance by car, and 4) transportation mode choice. These analyses are based on different datasets, dependent, and independent variables. Therefore uni-variate descriptive statistics and bi-variate analyses are not presented in this general chapter but in each analysis chapter separately.

6.1 Data Sources: National Household Travel Surveys

Two national travel surveys, the *National Household Travel Survey 2001 (NHTS)* for the U.S. and the *Mobility in Germany 2002 (MiD)*, were the main data sources for the multivariate analyses. The data for both surveys were collected in close time proximity: in 2001 for the U.S. and in 2002 in Germany. Both surveys were based on similar data collection methods and contain similar variables.[69] Understanding the survey methods and data collection techniques was crucial before using multivariate methods (Stopher, 2000). The following sections introduce and compare the two surveys and the variables

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[69] In fact, prior to carrying out the survey in Germany, one of the main German investigators was at Oak Ridge National Laboratories in the U.S. to study the NHTS.

that were added to the datasets. Similarities and differences of the two surveys were summarized in Tables 6.1 and 6.2 further below.

6.1.1 The National Household Travel Survey 2001 in the United States

The Nationwide Personal Transportation Surveys (NPTS) have been conducted every five to seven years by the U.S. Department of Transportation since 1969. The National Household Travel Survey (NHTS) 2001 is the latest survey in this series. The NHTS was the only national inventory on long and short distance travel—and more importantly for this dissertation, it was the only nationwide source for daily travel for all trip purposes.

The NHTS was carried out as a phone survey using random digit dialing (RDD). The RDD was used within a stratified sampling strategy making sure the survey covered all states and was representative of the U.S. as a whole, U.S. Census Regions, and certain metropolitan area size categories. The survey was administered from March 2001 to May 2002. Once respondents and their households had been identified via telephone and had agreed to participate, a household interview was conducted gathering information about the household. This initial interview collected general household information such as the number of household members, household income, or the number of cars owned.

In a next step, a datasheet or so called *travel diary* or *memory jogger* was mailed to all household members. The respondents were asked to record their daily travel activities in the travel diary on a day specifically assigned to them at random. After that day had passed the respondents were called and the data were collected by computer aided telephone interview (CATI). The overall final response rate for the NHTS was 41 percent with responses of 60,282 persons living in 26,082 households in all 50 states. Altogether the respondents made 248,501 trips. The initial response rate of household that participated in the screening interview was 58 percent. The response rate of 41 percent might seem low to the reader, but such response rates are fairly common for travel surveys (Kunert, Kloas, & Kuhfeld, 2002).

The author tried to obtain data to control for selection bias. Unfortunately, the U.S. Federal Highway Administration (FHWA) was not able to provide the desired data. RDD made it difficult to identify the exact sampling frame, as some phone numbers belonged to businesses and some households did have multiple phone numbers. FHWA collected data on all first-stage household screening interviews. Unfortunately, they had not analyzed the data by November 2007 and were not able to provide a dataset of all households contacted.[70] The only document provided was a non-response analysis carried out by WESTAT (2005). This analysis found that there was the potential for selection bias in NHTS. The researchers found that non-response rates were higher for lower income groups. Non-response rates were also associated with few years of education, primarily renter occupied census tracts, low household incomes, high percentages of African American and Hispanic in the census tract, and unemployed households (WESTAT, 2005). NHTS provided weights that control for selection bias according to the criteria identified above.

The NHTS included several changes in methods and content compared to its predecessors. Multiple prompting of questions relating to walk and bicycle trips was the most important modification (ORNL, 2004). Previous surveys underreported short trips by foot or bike—as respondents forgot to account for shorter non-motorized trips. Non-motorized trips have gained importance for researchers and policy makers. Walking and cycling are sustainable modes of transportation with many potential benefits to the

[70] The data had been misplaced during moving offices.

environment, the economy, and public health. The change in questioning seems to have been successful in capturing more walk trips: the NHTS shows higher numbers for non-motorized trips than its predecessor NPTS (Pucher & Renne, 2003).[71]

6.1.2 The Mobility in Germany 2002 Survey

The MiD for Germany was the latest survey in the KONTIV (Kontinuierliche Verkehrserhebung) series. The KONTIV surveys have been carried out four times: in 1976, 1982, 1990 and 2001. The next survey was planned for 2008/2009. The MiD was the first comprehensive travel survey for Germany, since its reunification in 1989.

Similar to the NPTS/NHTS surveys the German travel survey underwent several changes in methodology over time. Holz-Rau and Scheiner (2006) compared the methodology of the KONTIV studies over time and found major methodological differences between MiD and its predecessors. Luckily for this dissertation these changes made the MiD more similar in methodology to NHTS. Specifically the use of computer aided phone interview technology (CATI) and the use of a *travel diary/memory jogger* were adopted from the U.S. surveys. Holz-Rau et al. (2006) found that the use of telephone interviews and travel diaries for the MiD study might underreport work trips—a similar claim made in 1995 when the NPTS first introduced travel diaries. While these

[71] Due to changes in methodology, trend data on travel comparing the NPTS/NHTS surveys from 1969 to 2001 were difficult to analyze for several reasons. First, the 1995 NPTS introduced the concept of a travel diary, requiring respondents to track their travel behavior on paper and then use the diary for trip reporting. As a result the number of non-work related trips reported increased compared to prior surveys, which only required respondents to recall trips from their memory. Second, in 1995 for the first time joint trips of household members were combined in one database, prompting questions to verify joint trips in respective interviews with household members. If household member A was on a trip with member B, then the interviewer would ask household member B to verify the information given by household member A. Third, the definitions for metropolitan areas were changed between the 1983 and the 1990 NPTS survey. The most significant differences in definitions is that surveys after 1983 display a much larger number of households located in metropolitan areas of three million and more inhabitants than earlier.

changes constituted a problem for comparability of travel surveys over time within the two countries; it increased the comparability of the American and German surveys for this dissertation. The MiD for the first time included children younger than six years old (as did the NHTS). Additionally, the MiD offered interviews in Turkish for the first time. This is similar to NHTS survey interviews conducted in Spanish.

The data collection in Germany worked similar to the U.S. Households received an initial letter by mail introducing the survey. In a next step, if a phone number was available, respondents were called by phone. If the phone number was not available a paper survey was mailed to the household. Once households had agreed to participate in the survey they underwent an initial household interview, received a *travel diary* and were randomly assigned a travel day. Respondents who initially received a paper based survey were offered the possibility to switch to a phone based survey. This option was used by 80 percent of initial paper survey recipients, who switched to the phone survey. A phone call shortly before the travel day reminded the respondents to record their travel behavior on the travel day. Once the travel day had passed the household members were called and the data were collected. For some respondents (about five percent) where no phone number was available and who did not want to switch to the phone based survey (CATI) the data were collected through a paper survey (PAPI).

The response rate for the German survey was similar to the U.S. survey (42 percent), with 25,848 households responding, representing 61,729 persons making 165,367 trips. The response rate for the initial household screening interview was 58 percent.[72] Similar

[72]The screening interview was conducted as mail and phone survey. Sixty percent of households could be contacted by phone (CATI); 40 percent were contacted with a paper survey (PAPI). The response rates were 42 percent for PAPI and 68 percent for CATI. The combined response rate of 58 percent was calculated by weighting the PAPI and CATI response rates.

to the NHTS, researchers conducted a study on non-response and sample selection for the MiD (DIW 2004). The non-response study was based on interviews with households who refused to participate in the survey and only found minor signs of selectivity. Resident aliens, individuals older than 64, individuals from large households, and individuals who made many trips per day were underrepresented in the survey. Unfortunately, the non-response sample was very small so that the margin of error of these estimates is very large. They also controlled for differences between household who participated in the initial screening interviews and households who completed the travel diary. No significant selectivity was found (DIW, 2004).

Both datasets included respondents who were not traveling on the day of the survey; therefore not making any trips on that particular day. The percentage of individuals who stayed at home during the travel day was 13.5 percent for Germany and 12.7 percent for the U.S.

Both surveys had an initial target of including 25,000 households. NHTS and MiD included only responses from households where data for at least 50 percent of all household members could be collected. The U.S. survey additionally included variable identifying households where all household members responded.

Table 6.1 summarizes major similarities and differences of the two national travel surveys. Some of these similarities and differences are discussed in more detail in the two sections following this one.

Table 6.1 Similarities and Differences of MiD 2002 and NHTS 2001

Type of Survey	National Travel Survey	National Travel Survey
Population	Population of Germany (including foreigners, kids and institutionalized population if listed in government database (citizen registry))	U.S. population (including foreigners, kids and students in dormrooms of less than 10 people; prisons, nursing homes excluded)
Survey Method	CATI (95%) and PAPI (5%)	CATI (100%)
Sampling Strategy	Stratified random sampling from citizen registry	List assisted random digit dialing in all 50 states and D.C.
	340 sample clusters in 300 municipalities randomly selected by states	sampling frame: all telephone numbers in 100 banks of numbers (8 digits) with at least 1 residential number
	Random sample of population in citizen registry of these sample clusters	only residential phone numbers eligible
	stratified by population size of settlements, and regional classification (center, suburban, rural)	stratified by census divisions, and regional classifications (metropolitan area city and suburban areas and rural areas)
Target sample size	25,000 HH	25,000 HH
Response Rate	42%	41%
Persons	61,729	60,228
HH	25,848	26,082
Day-trips	167,851	248,512
Criteria for inclusion	all HH where over 50% of HH members responded	all HH where over 50% off HH membbrs ov18 years old responded

Continues on next page

Contact/ data collection procedure	Introductory letter; then phone call if number available; otherwise letter and written survey(1); HH level data collected from one HH member	If address available, introductory letter; then phone call; otherwise direct phone call; HH level data collected from one HH member
	A travel day was assigned before calling the HH, then travel diaries were mailed for all HH members.	A travel day was assigned before calling the HH, then travel diaries were mailed for all HH members.
	Reminder call/letter before day of travel	Reminder call/letter before day of travel
	Travel day data was collected by phone 1-14 days after travel day	Travel day data was collected by phone 1-6 days after travel day (occasionally to 10 days possible)
	Proxy interview with parent for all children less than 10 years old; for 10-13 year olds parents could decide on proxy interview	proxy interview with parent for all under 14 years olds; for 14-15 year olds parents could decide on proxy interview
	Combined data collection for joint trips of HH members (confirming joint trip by asking both respondents who they undertook the trip with)	Combined data collection for joint trips of HH members (confirming joint trip by asking both respondents who they undertook the trip with)
Non-response	Collection of HH data of non-respondents; special face to face interviews with 700 non-responders	Collection of HH data of non-respondents if possible
Bilingual interviews	Turkish offered, but never used. Other HH members helped as "interpreters" on the phone	1.9% of interviews conducted in Spanish
Weights	Initial weight is reciprocal of known probability of selection (based on HH-size)	Initial weight is reciprocal of known probability of selection (HH members per phone numbers)
	Adjustments for non-response based on HH-size, regional characteristics, day of the week and month of the year	Adjustments for non-response based on HH-size, regional characteristics, day of the week and month of the year (through a raking procedure)
	Trimming of large weights	Trimming of large weights

(1) With possibility to switch to CATI, which 80% of PAPI respondents did.

Sources: (DIW, 2004; ORNL, 2004, 2005; WESTAT, 2005)

Both surveys were representative of their respective national populations. The MiD survey was additionally representative of every German state. The NHTS was representative of the U.S. as whole, U.S. Census Bureau regions, and certain metropolitan area size categories. Both surveys relied on a complex weighting procedure to allow one to estimate representative national and disaggregate statistics of travel behavior. For the multivariate analyses, however, un-weighted and weighted data were used.[73]

The two surveys consisted of four datasets each: a household file, a person file, a daytrip file, and an automobile file. The units of analysis varied between the datasets and were the household (household file), the individual (person file), person trips per day (daytrip file), and automobiles used for the trip (auto file) respectively. All datasets were connected with each other through identifiers. Every trip was associated with a person, every person was associated with a household, and every car was associated with its household and a trip (if it was made by car).

For the user of both datasets it was not possible to access information about the exact location of the respondent's household. The only information given was the state of residence and the size of the respondent's metropolitan area. For the U.S. the Federal Highway Administration provided a geo-coded file identifying the census tract location of the household. While these data were confidential for the U.S. and obtaining it required additional paperwork; these data were not available for Germany at all—as they were declared classified by the German Federal Ministry of Transportation.

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[73] Models were estimated with and without weights. T-tests showed that the differences in coefficients are not statistically significant between models with and without weights. Additionally, the analyses are based on subsets of the datasets and the weights might not be appropriate for every subset. For these two reasons the weights were not used for the analyses.

Even though many similarities could be found for the two the surveys, differences still existed. One major difference between the surveys was the use of the German citizen registry as a sample frame for the multistage cluster sampling. In Germany, every inhabitant was required by law to register with local authorities. These personal data were collected in a so called citizen registry. For the MiD a list of all German municipalities was compiled. Then, in a first stage, 365 municipalities were selected randomly within German states. The exact number of municipalities was based on statistical representativeness and financial constraints—as citizen registries for each municipality had to be purchased from state governments. In a second stage, respondents were selected randomly within these municipalities. As mentioned above the NHTS relied on RDD for selection survey participants—as there was no national citizen registry in the U.S., which could have served as sampling frame. The sampling frame for the U.S. consisted of all 100-banks of phone numbers with at least one residence; phone numbers also included businesses. ORNL (2004, p. 3-4) defines 100–banks of numbers as *"a set of 100 telephone numbers with the same first eight digits, that is the same area code, exchange, and the next two digits."*[74] The phone numbers were sorted according to census divisions, and metropolitan area. All phone numbers had an equal probability of selection.

The German survey also included respondents living in institutions (such as student dorms), who were registered in the mandatory national citizen registry. Residents of institutions were excluded from the U.S. survey. The table below summarizes the comparability of both surveys relative to variability in other national travel surveys (NTS) worldwide. The second column gives the range of divergence between NTS

[74] http://nhts.ornl.gov/2001/usersguide/chapter_3.pdf

worldwide. Columns three and four compare MiD and NHTS. The grey color indicates relative comparability of MiD and NHTS compared to other NTS.

Even though differences between MiD and NHTS existed, they were probably the most comparable travel surveys to date for international comparative research. Comparative research has traditionally often been plagued by differences in methods, timing, geographical scope, content and purpose of data collection. MiD and NHTS were a unique opportunity for an international comparative study, based on two methodologically similar national travel surveys, with almost identical timing, that capture travel behavior for all trip purposes.

Table 6.2 Potential Sources of Divergence in National Travel Surveys and Comparability of MID and NHTS

	Range of NTS*	***MiD (Germany)***	***NHTS (U.S.)***
Survey Period	*10 weeks to 14 months*	14 months (11/01 - 12/02)	14 months (03/01 - 04/02)
Collection Rhythm	*annually to irregularly*	76, '82, '89, '02	69, '77, '83, '90, '95, '01
Sample Size	*3,000 to 63,000 HH*	25,848 HH	26,082 HH
		61,729 individuals	60,228 individuals
		167,851 trips	248,512 trips
Survey Method	*phone, person, mail*	CATI (95%)	CATI (100%)
Target Population	*civilian population*	civilian	civilian
Eligibility of HH Members	*adults, children, age cap*	adults and children	adults and children
Sampling Technique	*RDD to pop. register*	stratefied rand. sample	list assisted RDD
Survey Period	*1 to 7 days*	1 day travel diary	1 day travel diary
Response Rates	*often below 40% of HH*	42% of HH	41% of HH
Inclusion Criteria		HH where at leat 50% of HH members respondend	HH where at leat 50% of HH members over 18 yearsold
Nonresponse Treatment		collection of HH data	collection of HH data
Weights		selection reciprocal, non-response, HH size, weekday, month, regional charactertistics	selection reciprocal, non-response, HH size, weekday, month, regional charactertistics
Data Level	*HH, person, trip, or car*	HH, person, trip, car	HH, person, trip, car
Representative	Country, subsections	Germany, States	U.S., Census Regions
Add-ons		Yes	Yes

**based on nine recent national travel surveys; Source:(Kunert et al., 2002)*

6.2 Adding Data to the National Travel Surveys

Some variables were readily available for comparison in both datasets. These variables just had to be transformed to make them fully comparable for a multivariate analysis.[75] Besides these readily comparable variables some variables had to be added to the datasets, and others had to be transformed or generated for the purpose of the analyses.

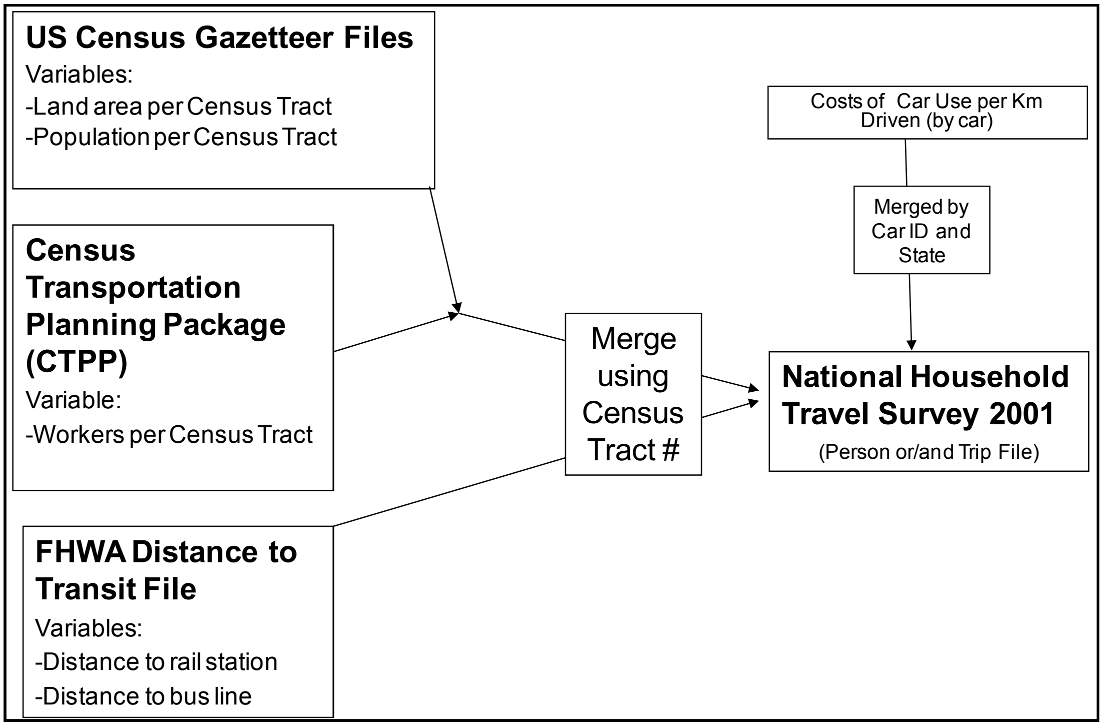
Data that had to be added to the dataset include residential and workplace density, costs car use, metropolitan area size category (for Germany only), and distance of household location to a transit stop (U.S. only).[76] Variables that had to be transformed were household income, mix of land uses, and relative and generalized costs of travel by different modes. The procedures for adding and transforming data are explained in detail in the next sections.

6.2.1 Adding Workplace Density and Distance to Transit Variables to the NHTS

The different variables and datasets added to the NHTS and the merging processes are depicted in Exhibit 6.1 below.

[75] Variables for the analyses and their exact measurement are introduced in the analyses chapters.
[76] Other variables, such as statewide population density, statewide length of non-local road network and statewide vehicle miles of transit service were added but proved to be too aggregate (crude) to be effective predictors in a individual level dataset. Therefore they were not described in this section.

Exhibit 6.1 Merging Population and Employment Density, Distance to Transit,



Transportation Supply and Cost of Travel Variables with the NHTS
Sources: (BMVBS, 2003b; ORNL, 2003; U.S. Census Bureau, 2006a, 2006b)

Workplace Density

The Federal Highway Administration (FHWA) provided a special version of the NHTS datasets, which allowed one to identify the census tract of each respondent's household. Obtaining the census tract identifier made it possible to add data on workplace density to the NHTS. Workplace density on the census tract level did not exist as single variable in any dataset, but had to be generated using data from two sources on (1) the number of workers and (2) land area of the specific census tracts. The ratio of number of workers at their workplace location over land area per census tract was then used as workplace density variable. The data added to the NHTS originated from the U.S. Census 2000 long form, "*Census Gazetteer*" files, and the U.S. Census Transportation Planning Package (CTPP). The FHWA provided an excerpt file of the CTPP containing the number of workers at workplace location per census tract.

Combining the land area per census tract from the Gazetteer files and workers at workplace per census tract from CTPP allowed generating workplace density per census tract.[77,78]

FHWA also provided a special file indicating the distance of any given household to rail stations and bus corridors. This variable existed in the German dataset already. The distance to rail stations data were an exact measure of household and train station location. The variable on household distance to a bus corridor overestimates accessibility to bus transportation, as not every point on a bus corridor was a bus stop. However, many U.S. bus transit providers allowed pickup along their routes—whenever a passenger signaled the desire to get on board busses may stop. Therefore the measure of distance to bus corridor was not a bad measure.

6.2.2 Adding MSA Categories, Residential, and Workplace Density to the MiD

Some variables had to be merged to the German dataset as well. As for the NHTS, the variables added and merging procedures used for MiD are depicted in Exhibit

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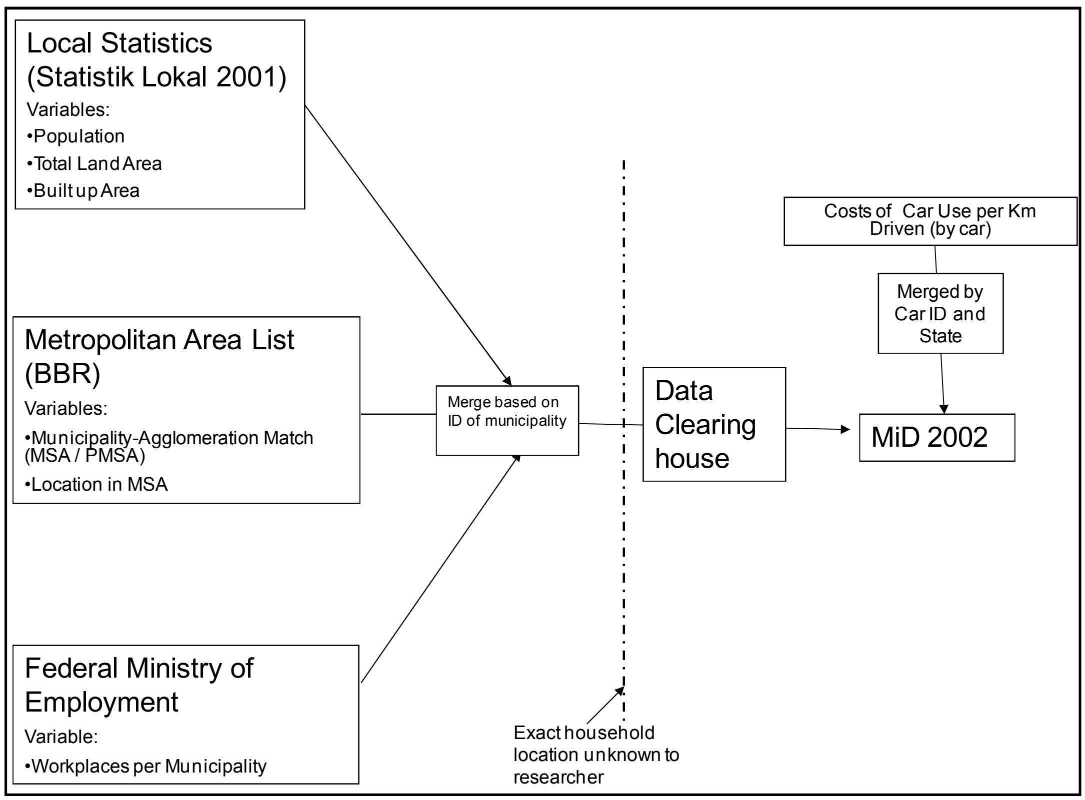
[77] Unfortunately the CTPP did not allocate all workers to exact census tracts. Some workers were only allocated to the county they worked in and not the exact census tract. In order to merge the data with the NHTS the exact census tract per worker needed to be identified. Out of a total of 128.2 million workers 8.9 million (or 6.8 percent of all workers) were only allocated to counties by CTPP and not to exact census tracts. These workers were assigned to census tracts within their counties, assuming that the distribution of these unallocated workers over the census tracts in the county is the same as for the workers already allocated to census tracts within the respective county. If a certain census tract within one county had *x* percent of all allocated workers in a county, it was assigned *x* percent of unallocated workers. This inflated the number of workers per census tract but left the relative percent distribution of workers across census tracts intact.

[78] The merge of the workplace density variable with the NHTS yielded 274 NHTS households located in 44 different U.S. states, which did not match any Gazetteer/CTPP census tract. This is about one percent of all NHTS households. The largest number of households from one single state was 22 from Virginia and 20 from Texas and Pennsylvania. In total the NHTS includes 1,332 households from Pennsylvania, 1,478 from Texas and 737 from Virginia. Therefore the non-matching households constitute 1.3 percent of Texas households, 1.5 percent of Pennsylvania households and 2.98 percent of Virginia households. Virginia was the state with second highest ratio of missing households. The highest percentage of missing households out of all households for a single state was four percent (South Dakota), the lowest 0 percent for seven states (Arkansas, Washington DC, Hawaii, New Mexico, Utah, Vermont, Wyoming). Furthermore the missing households constituted 0.5 percent of all urban and 2.9 percent of all rural households (99 urban and 181 rural households).

6.2 below. The merging process was more complex than for the U.S. data, however. The exact location of German households has been declared confidential by the German Federal Ministry of Transportation. Data had to be compiled independently and then be submitted to the "*German Transportation Data Clearinghouse*", which merged external data with the MiD survey.[79]

Exhibit 6.2 Merging Population and Employment Density, Metropolitan Area Size, Transportation Supply and Cost of Travel Variables with the MiD



Sources: (ADAC, 2002; BMVBS, 2003b; DESTATIS, 2003b, 2005; German Federal Agency for Employment, 2006)

The German dataset did not include population size categories for agglomerations comparable to U.S. MSAs. It also did not entail residential and workplace densities. Officially, Germany did not designate metropolitan areas in the same way the U.S. did.

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[79] This added a considerable amount of work. As mentioned above the exact municipality of households was unknown; therefore data for the merge had to be compiled for all German municipalities. The merge then only used a fraction of these data.

Internally, the German Federal Agency of Spatial Planning (BBR) compiled lists of German municipalities, their affiliation with metropolitan areas similar to the U.S., and their location within the metropolitan area. The location in relation to the central city was defined in terms of commute patterns. This classification contained the name of the municipality and the German municipality identification code, but neither the number of inhabitants per municipality nor information on residential or workplace density. Based on the municipality identification code the number of inhabitants per municipality for the year 2001 (December) could be obtained from the Federal Statistical Office's (Destatis) database "*Statistik Lokal*" (Local Statistics).[80]

Aggregating population numbers of municipalities over respective metropolitan areas defined by BBR yielded the population size of the metropolitan area. Population size was then categorized according to the NHTS data: more than three million, 1 to 2.9 million, 500,000 to 999,999, 250,000 to 499,999 and less than 250,000.

The "*Local Statistics*" database also included information on total land area, settlement area, and land area used for transportation infrastructure per municipality. Dividing population by total land area or by settlement and transportation area yielded two different measures of population density. Population density per settlement and transportation area was the preferable measurement for population density as it only included settled land area and excluded open farmland, bodies of water or forests within a

[80] Unfortunately, the data defining the metro-areas were based on 2005 municipality identification numbers and population size of municipalities was only available for the year 2001, when the survey was carried out. Many municipalities in East Germany had changed their municipality identification code between 2001 and 2005. They had been amalgamated with neighboring municipalities or municipalities had split into separate municipalities. With the help of BBR and the "German Transportation Data Clearinghouse" (DLR) municipality names and corresponding identification codes could be tracked for the 2005 and 2001 data.

municipality.[81] The German ministry of employment provided data on the number of workplaces per municipality. This data were merged with the municipal land use data, so that the variable workplace density could be generated.

For both countries the variables on population and workplace density were combined to create a mix-of-land-uses variable. Values for this variable range from 0 to 1. Values close to1 indicate a perfect mix (balance) of workplaces and population. Values close to 0 imply segregated uses, either mainly residential or mainly workplaces.

6.2.3 Adding Cost of Travel Variables to Both Datasets

The German dataset did not include information on travel costs other than travel time. The U.S. dataset contained information on costs per mile driven for each automobile, based on a prior study by the Federal Environmental Protection Agency.

For the German dataset costs per kilometer driven were added to the vehicle file using a dataset published by German AAA (ADAC Autokosten). This dataset contained information on costs per kilometer driven given gasoline prices and characteristics of automobiles. These characteristics included make, model, strength and type of car engine. An identifier variable was generated consisting of make, strength, and type of engine in MiD and the ADAC dataset. This variable served as merging identifier for the MiD vehicle file and the ADAC file. Not all cars in MiD could be merged with ADAC

[81] For the state of Brandenburg the data for settlement and transportation area did not exist, only the total land area for municipalities was given. For all other German municipalities the ratio of settlement area to total area was known. The data also identified the location of municipalities in relation to a city, e.g. central city, suburb, or rural area, for all German municipalities including Brandenburg. Tentatively the ratio of built up area over total area was larger for more urbanized places. In order to gauge the settlement and transportation area for Brandenburg's municipalities the total land area was multiplied by the German national average ratio of settlement area over total area by settlement category (city, suburb, or rural). This was only an approximation, but the closest way to estimate actual settlement area, taking into account the location of a municipality.

Autokosten. Vehicles that existed in MiD, but no data were available from ADAC Autokosten, were assigned average values for their car characteristic group.[82]

Table 6.3 Data Merged with NHTS and MiD: Source and Level of Aggregation

Germany		
Data Merged with Survey	***Data Source***	***Level of Aggregation***
Metropolitan Area Size	BBR (Metropolitan Regions 2003)	Municipality
Population	Destatis (Statistik Lokal 2003)	Municipality
Employment	German Employment Agency (2006)	Municipality
Transport Area	Destatis (Statistik Lokal 2003)	Municipality
Cost of Driving	ADAC (2002)	Vehicle
USA		
Data Merged with Survey	***Data Source***	***Level of Aggregation***
Employment	FHWA (CTPP 2003)	Census Tract
Land Area	U.S. Census Bureau (Gazetteer 2000)	Census Tract
Population	U.S. Census Bureau (Gazetteer 2000)	Census Tract
Distance to Transit Service	FHWA (NHTS/ORNL 2003)	Household

Sources: (ADAC, 2002; BMVBS, 2003b; DESTATIS, 2003b, 2005; German Federal Agency for Employment, 2006; ORNL, 2003; U.S. Census Bureau, 2006a, 2006b)

6.3 Manipulating Existing Data Available in NHTS and MiD

For both datasets, data for some individuals were missing in the person or trip data file, but were available in the household dataset (e.g. employment status, household distance to transit, or driver's license ownership). This was the case when individuals refused or forgot to respond in the person interview, but data about them had already been collected in the initial household interview. In these cases missing data points on the trip or person level were filled in with information gathered during the household interview.

Household income proved to be a very difficult variable to compare. For Germany monthly net household income was reported in Euros. The NHTS gave annual gross household income in U.S. dollars. For the multivariate comparison the German

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[82] Costs per kilometer driven were not merged to the exact car, but to a group of cars with similar make, engine and size characteristics.

household income was multiplied by 1.06 to adjust for purchasing power, and then the German monthly income was multiplied by 12 months and by 1.33 to adjust for the average income tax paid (Jolley, 2003).[83] This still potentially underestimated German incomes as many employees received 13 monthly salaries for a year of work. Additionally, many employees paid additional non-tax transfers to the government (so-called "*Abgaben*"). To overcome these uncertainties the 1.33 tax adjustment factor from OECD was attuned upward to 1.5.[84] Furthermore, for the German dataset the variable on household income had many missing data points, which had to be imputed using a *hotdeck* method.[85]

For the analysis of mode choice, data on the relative attractiveness and competitiveness of the automobile, transit, walking, and cycling are of special interest. The datasets did not include variables comparing the cost of travel for different modes of transportation. Data on the monetary cost per kilometer of travel for car were merged to

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[83]See specifically pages 14 and 73.

[84] Another approach was also tried: it transformed into percentiles for both countries ranging from 0 to 100. This, however, did only capture relative differences in income and not real dollar differences in income.

[85] For Germany the household income variable had 9,052 missing values (about 15 percent of respondents). The missing values were found to be MAR (missing at random). For this variable income was imputed on the household level using a hotdeck method. This method imputes values for missing data based on similar cases. For household income the variables household members 18 and older, vehicle ownership per household, location of household in East or West Germany, and regional classification (urban, suburban, and rural) were used to impute household income. Hotdeck creates groups of cases based on the variables identified (e.g. households with twomembers, twocar, in West Germany in rural areas). It then identifies cases with missing values with the same characteristics (e.g. households with twomembers, twocars, in West Germany in rural areas). Hotdeck selects one of the existing values for income to the missing data point. In other words, each case with missing income was assigned an income randomly selected from the existing income of similar cases.
In a next step the influence of the imputed values on the analysis was tested. Ideally, the imputed values should not have an independent influence on the analysis. A regression was estimated with distance traveled as dependent variable and three independent variables: (1) the household income variable including the imputed values, (2) a dummy variable identifying the imputed values as imputed, and (3) an interaction variable calculated by multiplying the dummy variable with the income variable. In this regression the dummy variable and the income variable were found to be not statistically significant (t-values of 0.3 and -0.93). Therefore it is concluded that the imputation did not have an impact on the final results. The final regression models were performed with and without the imputed values. No statistically significant difference between imputed and un-imputed version of the income variable could be found.

the data, as explained above. This still did not include cost of travel for transit, walking, and cycling.

In the literature, travel speeds were commonly used as approximation for attractiveness of transportation modes. The faster one mode was compared to another, the more attractive and easier it was to use. The data in MiD and NHTS gave speeds for trips made by respondents. No information was available for potential trip speeds for alternative modes of transportation. For example, if a car trip was made, then only the speed for this car trip was available, but no potential alternative transit, bike or walk speeds. For every trip respondents made, they were assigned relative speeds of their mode of transportation compared to the automobile based on trip distance.[86] If respondents used the automobile for a trip, then they were assigned a mix of costs comparing the car to all other modes of transportation for that trip-distance category. This variable will be more fully explored in Chapters 9 and 11 on the mode choice analysis.

6.4 General Modeling Approach

The following chapters use multivariate methods to investigate differences and similarities in travel behavior in Germany and the U.S. The analyses were based on datasets from NHTS and MiD introduced above.

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[86] Based on differentials in travel speed across trip-distance categories one more variable capturing generalized travel costs was generated. This variable consists of travel time by mode and travel distance. Travel time was multiplied by average hourly salary for the household income category (based on household income quartiles). This gave a monetized value of travel time based on travel speeds for every mode and travel distance. For public transportation and the automobile an additional dollar amount for the cost per mile traveled was added (capturing ticketing and gasoline costs). Then a ratio of generalized costs of travel was calculated similar to the relative speed variable introduced above. The author preferred the relative speed variable however, as many assumptions had to be made for the calculation the generalized cost variable. For example hourly salary per income quartile and transit costs per passenger kilometer were only available at the state level.

Given the constraints of cross-sectional individual level data for both countries, this dissertation could not model explanatory factors for differences in travel behavior directly.[87] The analytical strategy chosen (1) explored differences and similarities in travel behavior within and between the countries, (2) evaluated the contribution of explanatory factors to explained variability within countries, and (3) tried to capture the importance of explanatory factors for inter country differences through simulations.

First, models that compared the influence of different explanatory factors on travel behavior within each country were estimated. Based on these models similarities and differences in explanatory factors were compared between the countries. Second, a modeling strategy was employed that allows one to identify the amount of variability in travel behavior that was attributable to different explanatory factors. Finally, simulations based on estimated equations helped explain differences in travel behavior between the two countries.

Variability in travel behavior across countries could be explained by dissimilarities in socioeconomic and demographic variables, spatial development patterns, transportation policies, cultural preferences, and differences in the macro-

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[87] The nature of cross-sectional national level data for the datasets for both countries did not allow modeling differences in travel behavior between the countries directly. Different subsets of the two datasets could be used to capture differences across countries. For example similarly dense states in the U.S. could be compared to states with a similar density in Germany. This analysis would control for spatial development patterns and could show, which differences remain once density is controlled for. Alternatively, a multiple country or city study with aggregate units of analysis could help identifying differences in travel behavior directly. Shortcomings of aggregate level studies were already discussed in the literature review. First, aggregate level studies hide variation among individuals and across geographic areas. For example, comparisons across national or metropolitan averages hide variation within different parts of countries or within different locations in a metropolitan area. Second, aggregate studies cannot give insights into individual travel behavior and decision making. The decisions on what transportation mode to choose and how far to travel are made by individuals specific to individual circumstances. Variables such as income, car ownership, access to transit, land uses, pricing, and other policies can vary widely among people and within countries (Giuliano and Narayan 2005). If adequate data exist, multivariate statistical analyses with individual level data are able to best capture observed individual behavior (Crane 2000). Comparable data are often not available however.

economy. Equation (1) summarizes these factors in a general model for comparing similarities and differences in travel behavior:

[Equation (1): TB=f (TP, SD, SE, M, CP)]

TB=travel behavior
TP= transportation policies
SD=spatial development patterns
SE=socioeconomics and demographics
M=macroeconomic differences
CP=cultural preferences

These explanatory factors might have a different impact in each country, contributing to a unique transportation system. Only a few studies have attempted to use multivariate analyses based on individual level data to measure the relative importance of factors explaining international differences and similarities in travel behavior. Three different groups of regression models with different dependent variables were estimated. These three groups of dependent variables capture differences in (1) average daily travel distance per inhabitant, (2) average daily kilometers of car travel per inhabitant, and (3) individual choice of transportation mode.

All models were based on a pooled sample, which included information from the MiD and NHTS surveys. Models for average travel distance and average car travel distance were based on a pooled sample of 122,011 individuals from Germany and the U.S. Models for mode choice were based on a trip data file including a total of 416,349 trips made by individuals in the U.S. and Germany.

Each group of models was presented as a set of nested equations—where independent variables were entered one after the other. For example, all variables measuring transportation policies were included in the first model. Variables capturing spatial development patterns were added in the next model. The basic logic of the set-up of the models is presented in equations three through six below. Each subsequent model included the explanatory variables of the previous model(s) and adds a new set of independent variables. This allowed controlling for changes in total variance explained (R^2) for different groups of independent variables. It also identified omitted variables bias through changing signs and magnitudes of coefficients across the different models.

This approach had one weakness however: the order of entering groups of variables influences changes in R^2. In order to identify the unique contribution of each group of independent variables five separate models were additionally estimated; each with just one group of independent variables. Comparing R^2 for the five models allowed interpreting the magnitude of variance explained by each group of variable independently.

[Equation (2): (Model 1) TB = f (TP)]

[Equation (3): (Model 2) TB = f (TP, SD)]

[Equation (4): (Model 3) TB = f (TP, SD, SE)]

[Equation (5): (Model 4) TB = f (TP, SD, SE, M)]

[Equation (6): (Model 5) TB = f (TP, SD, SE, M, CP)]

Where TB, TP, SD, SE, M, and CP are defined as before.

The sequence of entering the variable groups was chosen based on theoretical interest, and novelty of independent variables for multivariate international comparative research. The main interest of this dissertation was in variables that can be influenced by policy makers and have not been or have only rarely been compared internationally through individual level data before. These variables were relating to spatial development patterns and transportation policies. Other factors such as cultural preferences or socioeconomics could not—or at least not easily—be influenced by policy makers. Additionally, the effect of socioeconomics and demographics has already been well established in international comparative research.

Model 1 included transportation policy variables only. Model 2 added variables relating to spatial development patterns. Model 3 then included socioeconomics and demographics. In contrast to policy and spatial development variables in models one and two, these variables have been analyzed in international comparative studies and their effects have been well documented so far. Model 4 additionally included a rough proxy for differences in the macro-economy between the countries.

This modeling approach allowed identifying the unique contribution of each group of independent variables. In Model 5 the unique contribution of cultural preferences could be assessed, once spatial development patterns, socioeconomics, and transportation policies had been controlled for.

The models, however, did not give insight into differences of explanatory variables within Germany and the U.S. An alternative modeling approach was employed to capture dissimilarities in magnitude and effect of explanatory factors on travel behavior between the countries.

Differences in magnitude, sign, and significance of coefficients between the countries were captured through *interaction effects* for Germany. This meant that for every independent variable one additional interaction variable for Germany was included in the analysis. Cultural preferences did not have an interaction variable, as cultural preferences were captured with a dummy variable (Germany=1, U.S.=0). Equation seven displays a general model for explaining international similarities and differences in travel behavior with interaction effects:

[Equation (7): TB=f (SE, SE(G), SD, SD(G), TP, TP(G), M, M(G), CP)]

Where TB, TP, SD, SE, M, and CP are defined as before. (G)=interaction effect for Germany.

These interaction variables were interpreted as the *relative difference* in the coefficient (or slope) of a variable in Germany compared to the U.S. For example, if a coefficient for the U.S. was α and the interaction effect for Germany showed a statistically significant coefficient of β, then the coefficient for this variable for Germany was the sum of the U.S. coefficient plus the interaction coefficient ($\alpha + \beta$)—in this case a stronger effect in Germany compared to the U.S. Opposite signs for α and β (e.g. plus for the U.S. vs. minus for Germany) indicated a weaker relationship in Germany compared to the U.S. Statistically non-significant interaction coefficients signaled a similar effect of the variable in Germany and the U.S.

[Equation (8): (Model 1a) TB = f (CP,TP,TP(G))]

[Equation (9): (Model 2a) TB = f (CP, TP, TP(G), SD, SD(G))]

[Equation (10): (Model 3a) TB = f (CP, TP, TP(G), SD, SD(G), SE, SE(G))]

[Equation (11): (Model 4a) TB = f (CP, TP, TP(G), SD, SD(G), SE, SE(G), M, M(G))]

Where TB, TP, SD, SE, M, CP, and G are defined as before.

Model 1 (a) included transportation policy variables and cultural preferences, which were measured with a dummy variable (Germany=1, U.S.=0). The choice of entering the cultural preference variable alongside policy variables in the first model was based on statistical necessities. The dummy variable was needed to interpret the Germany interaction effects of the policy variables and all variables entered into the model subsequently.

In models two (a) through four (a) other groups of independent variables and interaction effects were entered into the equation. In contrast to the first set of nested model introduced above, the dummy variable for cultural preferences was included in all models here. The unique contribution of the groups of independent variables could not be determined exactly, as culture was always accounted for already. Together with the first set of models the importance of individual factors could be identified however.

6.4.1 Interpreting Coefficients: Signs, Magnitude, and Significance

The coefficients of the independent variables were evaluated according to three criteria: (1) the sign of the coefficient, (2) its magnitude, (3) and its statistical significance.

First, the signs of the coefficients showed if theories of travel demand held true in both countries. If so, signs of coefficients should have pointed the same in both countries. For example, lower car ownership per household should have been related to less travel in both countries. An analysis of the signs of the coefficients for both countries compared the influence of independent variables.

Second, the magnitude of the coefficients was expected to vary between the countries. For example, residential density and distance to transit were expected to have a stronger effect in the U.S.; mainly because of greater discrepancies of population densities and less homogeneous access to transit there compared to Germany. Car ownership on the other hand was expected to have a stronger effect in Germany—as car ownership was not as universal there compared to the U.S. The reasoning behind these expected differences are more fully developed in the hypothesis section below. Most of these hypotheses were exploratory in nature and were tested empirically for the first time.

Third, the statistical significance of coefficients was interpreted and analyzed. This was especially important for the interaction effects for Germany. If an interaction effect was not statistically significant, it showed that the sign and magnitude of the effect of this variable were not significantly different in both countries.

6.5 Hypotheses for Multivariate Analysis

This section first introduces variables used to measure travel behavior, transportation policies, spatial development patterns, socioeconomic and demographic factors, and proxy variables for differences in the macro-economy, and culture. Then hypothesized effects of the independent variables on the dependent variables are stated. Hypotheses for similarities and differences in expected effects between and within the two countries are formulated.

6.5.1 Travel Behavior: Travel Distance, Travel Distance by Car, and Transportation Mode Choice

Travel behavior is operationalized in three different ways, which give rise to three sets of multivariate analyses: (a) *total daily travel distance* per person, (b) *total daily travel distance by car* per person, and (c) *transportation mode chosen* per person and per trip.

The goal of this dissertation is to describe and help explain variability in daily travel behavior using everyday travel modes. Trips by helicopter, yacht, cruise ship, intercity rail, airplane, and intercity bus were therefore excluded.[88,89] Total daily travel distance by car, transit, bicycle, and on foot can give insight into similarities and differences in the effect of explanatory factors on everyday travel behavior in both countries.

For the first two multivariate analyses, Ordinary Least Squares (OLS) regressions were estimated. Daily travel distance was regressed on transportation policies, spatial development patterns, socioeconomic and demographic variables, and proxies for macro-economic differences, and culture. The last analysis focused on explanatory factors for daily choice of transportation modes, including four choice categories: (1) automobile or light truck; (2) public transportation; (3) bicycle; or (4) walking. As in the other chapters, mode choice was regressed on transportation policies, spatial development patterns, socioeconomic and demographic variables, and a dummy variable representing culture. Additionally, trip purpose was included as independent variable in this analysis. Public transportation for example is best suited for the work trip, as transit efficiency is maximized for commuting.

6.5.2 Endogeneity and Self Selection in Transportation Research

Endogeneity and self-selection bias have always been problems for analyses of travel behavior. Endogeneity bias can occur (1) if independent variables are also a function of the dependent variable or (2) if independent variables are correlated with omitted variables (Cao, Mokhtarian, & Handy, 2006). In both cases estimators will be biased and inconsistent. These two conditions are often met in transportation and land-

[88] The MiD and NHTS are not intended to capture long distance travel behavior, therefore long distance trips only constitute a small percentage in both travel surveys (1.4 percent in MiD and 1.7 percent in NHTS).
[89] Both NHTS and MiD do include supplementary elements capturing long distance travel.

use research. The built environment influences travel behavior, but at the same time travel behavior also impacts spatial development patterns over time. In this case not accounting for the simultaneity of the influence might bias estimators. Furthermore, some researchers argue that the choice of household location and car ownership is associated with travel preferences and attitudes. Individuals, who wish to travel less by car might own fewer cars and locate closer to transit stops or in areas with higher population density and a greater mix of land uses. Not including specific variables about attitudes and travel preferences would lead to biased coefficients.

Several solutions exist to overcome these problems, such as statistical control, instrumental variable models, sample selection models, joint models, and longitudinal designs (Cao et al., 2006). All of them come with stringent requirements of comparability of variables and measurements in both countries and are hard to implement with just two cross-sectional surveys. If data were available the following three solutions could help:

(A) A longitudinal study design could help overcome these problems by providing before and after data on changes in individuals, travel behavior, and spatial development patterns. Such an analysis might be possible once NHTS and MiD 2008 data will become available.

(B) Both, MiD and NHTS could include questions asking for travel preferences of individuals. Explicitly, including these attitudinal variables would overcome a potential correlation of location choice and car ownership with the error term.

(C) Another possibility might lie in structural equation models (SEM), which allow for causation to flow in multiple directions among independent and dependent variables. SEM should ideally also include variables about travel preferences and attitudes. Unfortunately, SEM is based on the analysis of bivariate correlations, which is problematic with the large number of nominal and categorical variables included in this analysis. In practice researchers often use SEM with nominal and categorical values. Ideally, SEM could be combined with a longitudinal design, capturing changes over time.

6.5.3 Independent Variables and Hypotheses

Transportation policies, spatial development patterns, socioeconomic and demographic variables, macro-economic differences, and cultural preferences were operationalized as explained below. The selection of explanatory variables was based on theoretical guidance and empirical availability in the two enriched datasets. The hypotheses for the influence of the individual explanatory variables on travel distance were relatively straightforward. Expected differences between the countries were more difficult to hypothesize, as there were few prior multivariate studies comparing these influences between countries.[90] Therefore, hypotheses regarding the differences of effects between the countries were based on logical assumptions, but empirical analysis still had to show if they held true. For each variable an attempt was made to formulate expected effects for the overall sign of the coefficients and potential difference in their magnitude between the countries.

6.5.3.1 <u>Transportation Policies</u>

Transportation Policies were difficult to measure at the level of the individual, as these data were not available at a disaggregate level. Neither NHTS nor MiD collected

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[90] Only Giuliano et al. (Giuliano & Dargay, 2005; Giuliano & Narayan, 2003, 2004, 2006) used a similar modeling strategy.

data on transportation policies. The models estimated here included different sets of policy variables based on data availability. The models for daily travel distance included only one indirect measure of transportation policy: household distance from a transit stop. Models for daily car travel distance included three measures of transportation policies: household distance from a transit stop, car operating cost per kilometer, and relative speed of other modes of transportation compared to the automobile. Models for mode choice included two measures of transportation policies: household distance from a transit stop and travel speeds for all four modes of transportation.

Ideally, many other measures of transportation policies such as parking fees, gasoline prices, taxes on car purchase, the length of the local road network, transit vehicle kilometers of service, or transit fares should have been included in this analysis. Unfortunately, these variables were not available at the level of the individual trip maker.[91,92] Even if they would have been, multicoliniarity problems would most likely have prohibited using them simultaneously.

Household Distance from a Transit Stop

A household's proximity to a transit stop was a potential indicator of transit supply and accessibility in the absence of an automobile.[93] It was expected that in both countries individuals who lived closer to a transit stop would display shorter average

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[91] The analysis of total daily distance by car and mode choice will include variables relating to the cost of car travel and the relative cost of a car trip compared to other modes of transportation.
[92] Variables for vehicle kilometers of transit service per capita and length of non-local road network per inhabitant were assembled on the state (U.S.) and Land (Germany) level and added to the analysis. Unfortunately, they were not statistically significant for the individual level analysis. An analysis where distance traveled was aggregated to the state level showed that these variables have the expected effect on total daily travel distance. This analysis, however, only had 67 units of analysis (51 U.S. states including Washington D.C. and 16 German states) and was plagued by problems emanating from aggregation of data and limited degrees of freedom due to the small sample size.
[93] The second model, estimating vehicle kilometers of car travel, will include a measure of car operating (gasoline) cost per kilometer driven. Cost per kilometer driven is a function of energy efficiency of an automobile and the gasoline tax rate and price.

daily travel distances and shorter daily car travel distances than individuals in households farther away. Furthermore it was expected that individuals living closer to a transit stop would display higher levels of transit use, cycling, and walking than individuals in households living farther away from transit.[94]

Shorter daily travel distances for individuals living closer to transit stops were expected for the following reasons. First, public transportation trips were most likely combined with either walking or cycling as feeder modes at the origin and destination of a trip. Trips on foot, by bike, and by transit (including wait times) were generally slower than trips by automobile. Slower travel speeds resulted in shorter daily travel distances—assuming similar daily travel time budgets. Second, transit service was only economical at higher population densities. Therefore transit stops were most likely located in higher density and areas with a greater mix of uses —thus contributing to shorter distances from origin to destinations for activities such as shopping, exercise, or visiting friends. Moreover, denser areas generally had a lower supply of roads per capita—resulting in higher levels of traffic congestion and lower car travel speeds. Shorter trip distances might be related to (a) more trips on foot or by bike and fewer car trips or (b) shorter distances traveled by car, if that mode was chosen.

It was more difficult to predict differences between the countries in the effect of household distance to a transit stop on daily travel. Hypotheses explaining the differences were based on logical assumptions, but had to be proven empirically, as there were only few prior multivariate studies that compared effects between countries.

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[94] Some European studies indicate that public transportation and cycling are not necessarily complementary, but are competing against each other (Schwanen, 2002). Therefore cycling levels might be lower in Germany for individuals living close to transit.

It was expected that household distance to a transit stop may have a stronger effect on daily travel distance and daily car travel distance in the U.S. compared to Germany for the following reasons. Overall, Germans—no matter if they lived close to or farther away from transit stops—walked and biked more than Americans. Therefore trips in Germany had slower average speeds and shorter average distances than in the U.S. Due to more walking and cycling close and farther away from transit, average speeds and travel distances were more homogeneous in Germany than in the U.S. Additionally, German settlement densities were higher and road supply was more limited than in the U.S.—thus leading to more traffic congestion and lower overall car travel speeds and shorter overall travel and car travel distances. In the U.S. households farther away from transit made almost all trips by automobile, and thus at much higher travel speeds compared to households close to transit stops. For these reasons, the effect of living close to transit on daily travel distance and car travel distance was less pronounced in Germany compared to U.S.

For mode split the expectation was the opposite. Americans—no matter if their household was located in proximity or farther away from a transit stop—made most trips by automobile. This was related to spread out regional development patterns and land uses that were only accessible by car. More compact spatial development patterns in Germany made transit, walking, and cycling a viable alternative to the car for households close to a transit stop.

The hypotheses are stated below. Most of the hypotheses on differences in effect *between* the countries had to be empirically tested as there are no prior studies comparing these effects between Germany and the U.S. In fact the author is only aware of one research project by Giuliano et al. (2003, 2005, and 2006) that used a similar approach. In these studies, the authors did not generate any hypotheses prior to their multivariate analysis.

H1a: The closer a household is to a transit stop, the shorter the total daily travel distance and daily car travel distance will be in both countries

H1b: Transit access has a larger effect on travel distance in the U.S. compared to Germany

H1c: Transit access has a larger effect on mode choice in Germany compared to U.S.

<u>Operating cost per kilometer of car use</u>

For both countries, the operating cost per kilometer of car use was expected to have a negative effect on kilometers of car travel. Several factors contributed to this hypothesis. First, individuals who wished to travel more kilometers might have purchased a more fuel efficient car—thus leading to lower average operating costs per kilometer. For example, data showed that Germans who travel many kilometers a year were more likely to purchase a more fuel efficient diesel powered car (BMVBS, 1991-2007; DIW, 2006). Second, older cars were usually less fuel efficient and were—as shown by the two datasets— driven fewer kilometers per year compared to newer cars (BMVBS, 1991-2007; DIW, 2006; Golob & Brownstone, 2005)**.** Thus older cars with higher operating costs were driven less.

Comparing the difference in impact of operating costs on car travel in Germany and the U.S. was difficult. Usually elasticities for fuel demand and for demand of vehicle kilometers of travel were stated separately. The measure used here combined the two, as operating costs per kilometer take energy efficiency of the vehicle into account. In a review of demand elasticities Hanly, Dargay, Goodwin (2002), and Epsey (1998) found short term demand elasticities for *fuel* to be *more inelastic* in the U.S. than in Europe.[95] They also found that demand elasticities for *vehicle kilometers of travel* (VKT) were *more inelastic* than demand elasticities for *fuel.*[96] This might be related to the effect of increasing vehicle energy efficiency—resulting in slower growth in fuel demand compared to VKT. The studies showed that short term demand elasticities for *kilometers of travel* ranged from |0.05| to |0.17| with an average of |0.10|; and that demand elasticities for *fuel* ranged from |0.01| to |0.57| with an average of |0.17|. They concluded, however, that overall results of the studies were not consistent.

Litman (2007) reviewed demand elasticities for *fuel* and *vehicle kilometers of travel* for various countries. He found *more elastic* short term demand elasticities in the U.S., compared to international averages (|0.26| for the U.S. (based on a study by Schimek (1997)) and |0.15| internationally (based on a study by Glaister and Graham (2002)). DeJong and Gunn (2001) confirm Littman's finding. Lower demand elasticities internationally compared to the U.S. might be related to differences in elasticities for gasoline and diesel fuels. Bailly (1999) found that demand for diesel is *less elastic* than demand for gasoline; probably related to higher fuel efficiency of diesel engines. Diesel was much more common as a fuel for passenger cars in Europe than in the U.S. Given the diverging findings of studies above, the difference in coefficients for operating cost

[95]Here and in the following "lower" and "higher" refer to the absolute value of the elasticity. Demand price elasticities are always negative, however.
[96] No differences between Europe and North America were reported on VKT demand elasticities.

between Germany and the U.S. had to be evaluated empirically. Hypothesis 2b below followed Litman, DeJong et al. and Bailly.

H2a: Higher operating costs per kilometer leads to fewer km of car travel in both countries

H2b: Higher overall operating costs in Germany result in a smaller impact of operating costs per kilometer compared to the U.S.

<u>Travel Speed</u>

It was expected that faster average car travel speeds compared to other modes make the car more attractive. In the U.S. car travel speeds were 30 percent higher than in Germany in 2001/2002 (based on NHTS and MiD). Average speeds for other modes were comparable in the U.S. and Germany—thus making the car more attractive in the U.S. than in Germany. It was expected that relative speed was a good predictor for the choice to make a car trip or not. Therefore, this variable was included in the HSM models in Chapters 8 and 9. The variable and its exact measurement will be more fully introduced then. The expected effect for differences between the countries had to be determined empirically.

H3: The likelihood of choosing to travel by car increases as the relative speed of alternate modes decreases

6.5.3.2 <u>Spatial Development Patterns</u>

Spatial Development Patterns were conceptualized as (1) the size of the household's metropolitan area; (2) population density; and (3) mix of land uses at the household location. As described in this chapter, the variables of metropolitan area size and population density were added to the German dataset. The mix-of-land-use variable was added to both datasets. These three spatial development variables were hypothesized to have the following effects within each country and across countries.

Metropolitan Area Size

The larger a metropolitan area, the farther the trip origins and destinations are from each other, and the more kilometers an average person travels per day. Average car trips were expected to be farther in larger metropolitan areas. But larger metropolitan areas generally provided better public transportation. With more transportation options it was more likely trips were made by public transportation and not by car in large metropolitan areas.

No German agglomeration compared to the largest American metropolitan areas such as Los Angeles, New York, and Chicago. Therefore the difference between small and large metropolitan areas was expected to be more pronounced in the U.S. compared to Germany. In Germany, metropolitan areas were generally smaller than in the U.S. and spatial development patterns were more homogeneous due to strict land-use planning laws—resulting in more homogenous travel behavior across metropolitan areas.

H4: The larger a metropolitan area is, the longer daily travel and car travel distances are

H4b: As metropolitan area size increases, more trips are made by transit and relatively fewer trips are made by car

H4c: The effect of metropolitan area size is stronger within the U.S. compared to Germany

Population Density

Densely populated areas were expected to be associated with a higher share of trips made by transit, walking, and cycling. First, trip origins and destinations tended to be closer together in densely developed areas—thus resulting in overall shorter trips, more likely made on foot or by bicycle. Second, denser areas were more likely to be equipped with pedestrian and cyclist infrastructure, such as sidewalks or bike lanes—thus encouraging the use of those slower modes of transportation and not the automobile. Third, automobile trip speeds were generally slower in dense areas, due to higher levels of traffic, congestion, and less supply of road space. Shorter distances between trip origins and destinations, provision of pedestrian and bicycling infrastructure, and slower automobile travel in dense areas were expected to result in fewer kilometers of travel in both countries. Fourth, public transportation could only be supplied economically at higher population densities; therefore a higher percentage of trips was expected to be made by transit in denser areas compared to lower density settlements.

As explored in Chapter 5, stricter land-use planning laws and tight control of spatial development patterns have caused German settlements to be more homogeneous and generally denser than in the U.S. In the U.S. population density ranges from the rural Midwest to the crowded downtowns of New York City and Chicago. The difference of daily travel distance and car travel distance between low density and high density areas was therefore expected to be larger in the U.S. compared to Germany. More homogeneous densities of settlements in Germany resulted in a flatter slope for the population density curve in Germany.

Furthermore, in the U.S. regional spatial development patterns were generally more dispersed than in Germany. Even in densely populated metropolitan areas, such as

Northern New Jersey/New York/Connecticut, close to 80 percent of trips were made by automobile. There, even individuals residing in dense areas had to drive to many destinations outside of their immediate neighborhood. Supermarkets, doctor's offices, and work places were often only accessible by car. The difference of mode choice between low density and high density areas was therefore expected to be lower in the U.S. compared to Germany—resulting in a steeper slope for the population density curve in Germany.

H5a: Higher population densities result in generally shorter travel distances and a higher share of transit, walk, and bike trips

H5b: Population density is expected to have a smaller impact on daily travel distances in Germany compared to the U.S.

H5c: Population density is expected to have a smaller impact on mode choice in the U.S. compared to Germany

<u>Mix of Land Uses</u>

Mixed-use neighborhoods with work places and residential areas in close proximity were hypothesized to result in fewer daily kilometers of travel including car travel. The greater the mix of uses in a neighborhood, the shorter the potential distance between work and home resulting in fewer average kilometers of travel during a day and more walk and cycling trips. Settlements in Germany had a greater mix of land uses than their U.S. counterparts (Hirt, 2008). Zoning laws and the separation of uses have been less strict in Germany compared to the U.S. In Germany, areas zoned as residential have allowed small hotels/hostels, corner stores, small businesses, and doctor's offices, thus encouraging shorter average trip distances. In the U.S. the separation of uses has been much stricter, often not allowing any non-residential activities in areas zoned as residential. The result was a larger difference in travel distance and mode choice between single use and mixed land use areas in the U.S. compared to Germany.

H6a: Mixed-use in household location results in fewer daily kilometers of travel in both countries

H6b: Greater mix of land uses leads to fewer trips made by automobile

H6c: The effect of mixed use is expected to be smaller in Germany compared to the U.S.

6.5.3.3 Socioeconomic and Demographic Variables

Socioeconomic and demographic variables were measured as car ownership per household member, household income, respondent's employment and household life cycle status[97], respondent's gender, and if the respondent had a driver's license or not. All of these variables were given in the two datasets or were generated from the available data within MiD or NHTS. Another potential socioeconomic variable was education level, which unfortunately was measured differently in each dataset and therefore could not be combined. It was assumed that effects of educational level were captured through household income, which was higher for higher levels of education. The hypothesized effects for socioeconomic and demographic variables were stated below.

Vehicle Ownership

[97] Household life cycle status refers to the composition and employment status of a household and its members. The categories are single households, couple households without children, households with small children, households with school children, and retired households. These categories will be introduced more fully below.

Access to an automobile was expected to increase travel distances, car travel distances, and the share of trips made by car in both countries. Households with more cars per driver tended to make a higher share of their trips by automobile. Car trips were generally longer than walk, bike, and most transit trips. In the U.S. most households owned multiple cars and most Americans had easy access to an automobile when they needed one. Only eight percent of all households in the U.S. were without a car in 2001. Even among households with less than $20,000 annual income only 25 percent were car-free. Interestingly, individuals in households without a car in the U.S. still made 35 percent of their trips by automobile. Households with one or more cars made over 80 percent of their trips by car in the U.S. (Pucher & Renne, 2003).

In Germany car ownership levels were lower and the majority of households only owned one car. Twenty percent of all German households did not own a car and these households only made about 13 percent of their trips by car—a large difference compared to the U.S. Generally, fewer Germans had unlimited access to a car compared to Americans. If access to a car was limited, other modes of transport—with slower average speeds and shorter average trip distances—had to be chosen for the trip to happen at all. Easier access to a car led to faster average travel speeds and farther average trip distances. In contrast to Germany, in the U.S. all households—even the carless—made a considerable share of their trips by car. In Germany, carless individuals made a higher share of their trips on foot, by bike, or on transit, thus covering fewer kilometers per day compared to drivers.

Difference in total daily kilometers of travel and mode share between Germans who had very easy access to an automobile compared to those with limited car access were expected to be larger than differences in the U.S., where even individuals who did not own a car made a considerable share of their trips by car (Pucher & Renne, 2003).

H7a: Car availability per household member will result in more car use, longer daily travel distance, and car travel distance in both countries

H7b: Car access has a larger impact on daily travel distance, car travel distance and mode choice in Germany than in the U.S.

<u>Household Income</u>

Household income was expected to be positively related to total daily travel distance, car travel distance, and the percentage of trips made by car in both countries. In the U.S. all income levels were expected to travel longer distances than in Germany. Pucher and Renne (2003) found that even individuals in households with less than $20,000 annual income in the U.S. made over 75 percent of their trips by automobile. In Germany it was expected that poorer, often carless, individuals would travel much shorter daily distances—mainly by modes with slower average speeds such as by bike, on foot, or by transit. It was expected that household income had a larger effect on travel in Germany compared to the U.S., where all income groups cover longer travel distances most likely by automobile—as driver or passenger.

H8a: Higher household incomes result in longer average daily travel distances, car travel distances, and a higher share of trips by car in both countries

H8b: Differences in travel behavior between low and high income households are expected to be more pronounced in Germany compared to the U.S.

Driver's License

In both countries individuals with a driver's license were expected to travel more kilometers and to make a higher share of their trips by automobile. Differences in travel distance between individuals with and without driver's license were expected to be more pronounced in Germany than in the U.S. Prior studies have shown that in the U.S. individuals without a driver's license made almost 60 percent of their trips as passengers in automobiles. In Germany, adults without a driver's license made 75 percent of their trips by modes other than the automobile. Travel speeds of transit trips (with wait time), walking, and cycling were slower than car speeds. Therefore differences in travel distances between individuals with and without driver's license were expected to be more pronounced in Germany. The difference in mode choice between individuals with and without driver's license was expected to be weaker in the U.S. compared to Germany, where individuals without a license could use public transportation or walk and bike to destinations.

H9a: Individuals without driver's license travel fewer kilometers per day than individuals with driver's license in both countries

H9b: Differences between license holders and individuals without a driver's license are weaker in the U.S. compared to Germany

Age, Employment, and Household Life Cycle

Age, employment status, and household composition were expected to have an important impact on travel behavior. For example, children under driving age (16 in the U.S. and 18 in Germany), individuals who were not in the labor force or unemployed, and retired individuals were expected to travel less than employed 18-64 year old individuals in both countries. Driving an automobile was not possible for children under driving age, as well as for some elderly individuals—due to health conditions. These groups had to rely on slower modes of transportation or on a driver to give them a ride. Therefore their daily travel distances were expected to be shorter than for the rest of the population.

Household composition was also expected to have an influence on travel. It was expected that adults in adult-only households would travel less than in households with children. Children might have to be driven to the doctor, preschool or daycare, schools, and other activities—thus adding car trips to their parents travel. Furthermore, adults in households with small children younger than five years, were expected to travel less than adults in households with children older than five. Older children might participate in more activities such as sport teams, getting together friends, and music lessons than younger children and babies. Many of these destinations could only be reached by automobile—thus requiring rides from parents or older siblings.

Differences between all these groups were expected to be stronger in Germany than in the U.S. In Germany, children and the elderly had more possibilities to reach destinations on foot, by bike, or by public transportation thus leading to shorter average daily kilometers of travel for them and their parents.

H10a: In both countries individuals who are under driving age or retired are expected to make fewer trips by car and to travel fewer kilometers than 18-65 year old individuals. Individuals in households with children are expected to make a higher share of trips by car and to travel more kilometers than individuals in households without children.

Employed individuals are expected to travel more kilometers and make more trips by car than individuals not in the labor force

H10b: Differences in car travel are more pronounced in Germany compared to the U.S.

<u>Gender</u>

Prior studies for both countries have shown that men travel more and make a higher share of trips by car than women. The expectation was to find similar results in this study. Women in Germany had a more traditional role in society than in the U.S. For example, female workforce participation has been historically lower in Germany than in the U.S. (OECD, 2003-2007). Employed individuals were expected to travel more kilometers and make a higher share of trips by car than individuals who are not in the labor force or are unemployed—as the employed most likely made two additional trips to and from work each day. A lower female workforce participation rate in Germany was most likely connected to larger gender differences in travel than in the U.S. German women were more likely to stay at home and were therefore traveling substantially fewer kilometers than men, who are traditionally the household's bread winner in Germany. In the U.S. this difference was less pronounced due to a higher share of females in the workforce.

In both countries, the majority of work trips were made by car. Consequently, car access for women who were not in the workforce was more limited in Germany—as the car was most likely used by the male bread winner. German women had to rely on other modes of transportation, such as walking, cycling, or public transportation. In the U.S. homemakers made more trips by car as they have easy access to an automobile—and additionally walking, cycling, and transit were often not feasible alternatives, given spatial development patterns.

H11a: Men are expected to make a higher share of trips by car and to travel more kilometers than women in both countries

H11b: Differences in travel between men and women are more pronounced in Germany than in the U.S.

6.5.3.4 Other Differences

Macro-economic differences were difficult to include in an individual level analysis. One major difference between the U.S. and Germany was related to the overall level of economic activity. Americans worked more hours annually, mainly due to longer weekly work hours, fewer days of vacation, and fewer public holidays (OECD, 2003-2007). Similar to transportation policies these macro-economic differences were not easily included in an individual level analysis. One aspect of this might have already been captured through the employment status variable.

Additionally, the datasets included information on day of the week on which travel occurred. Travel on Sundays compared to weekdays could serve as a rough proxy for overall lower economic activity in Germany than the U.S. For example, supermarkets, malls, and other stores were commonly open on Sundays for customers in the U.S. In Germany, in general, supermarkets, malls, and other stores were closed on Sundays. There stores were only allowed by law to open on Sundays before major public holidays.[98] More shopping possibilities, as well as work trips for individuals working in

[98] Stores selling primarily tourist memorabilia are open all Sundays throughout the year.

retail businesses, might result in more travel activity on Sundays in the U.S. compared to Germany. This difference in travel on Sundays could serve as a very rough individual level indicator for overall macro-economic differences, such as more workdays and less vacation in the U.S.

In both countries travel distances were expected to be shorter on Sundays compared to weekdays. This effect was expected to be stronger in Germany, as in contrast to the U.S. most stores and workplaces stayed closed there on Sundays.

H12a: Compared to other days of the week, travel distance is shorter on Sundays in both countries

H12b: The effect of "Sunday" is stronger in Germany compared to the U.S.

Cultural Preferences have been often mentioned as explanatory variable for differences in travel behavior. Culture has been very difficult to measure and most multivariate studies treated it as a residual measure. Some potential sources of cultural differences between Germany and the U.S. were already included in the model: more traditional roles for women in Germany, different household composition, and store opening hours on Sunday might be indicators for cultural differences between Germany and the U.S. In the literature differences in travel witnessed between the U.S. and Europe were attributed to greater acceptance of government intervention, differences in corporate power over the transportation sector, and more concern about externalities of car use in Europe (Deakin, 2001; Dunn, 1981; TRB, 2001; Yago, 1984).

Here cultural preferences were measured through a dummy variable with a one for Germany and a 0 for respondents in the U.S. This variable captured all differences not included in the other variables in the model, however. Therefore, it was only a very rough proxy and one had to be careful interpreting this cultural preferences dummy since other factors could be included than cultural preferences.

H13: Americans are expected to make a higher share of their trips by car and travel more kilometers per day than Germans

Trip purpose also had an effect on travel behavior. This variable could only be included in the mode choice analysis, as trip purpose varies by trip. The first two analyses looked at travel distance and car travel distance for a given travel day, encompassing various trips with different trip purposes.

Transit service was well suited for commuting—as a large number of employees can be efficiently carried to employment centers in downtown. Additionally, most transit systems provided the highest frequency of transit service during morning and afternoon peak travel hours. Shopping trips were most likely made by automobile, as groceries and other purchases had to be carried home. For both, shopping and work trips it was assumed that individuals chose the mode, which minimized their travel time. Recreational trips did not necessarily fulfill this premise. For example, the time spent exercising (running or cycling), was the goal of these trips and might have been maximized.

H 14a: Compared to other trip purposes a higher share of work trips is made by transit

H 14b: Compared o other trip purposes shopping trips are more likely made by automobile

The following sections introduce the analyses for (1) daily trip frequency per person, (2) daily travel distance per person, (3) daily car travel distance per person, and (4) individual mode choice. Every section has the same analytical structure: (a) First the modeling approach is introduced; (b) next univariate statistics of dependent and independent variables is introduced; (c) then an analysis of bivariate relationships between independent and dependent variables is presented; (d) subsequently the estimated models and findings are described; (2) finally the last section of the multivariate analyses uses simulations to explore impacts of changes in independent variables on dependent variables in Germany and the U.S. The next chapter introduces variables, level of measurement, bivariate analysis and multivariate models for individual daily travel distance.

7 Number of Trips per Person per Day

In this dissertation, travel behavior is conceptualized as (1) number of trips, (2) travel distance, and (3) mode choice. Demand for travel is commonly understood as a function of individual demand for participation in activities outside of the home. Travel is the means to overcome spatial distance between the home and various activities. Within this framework, the number of daily trips (also known as trip rate) is a direct measure for demand of daily activities; more trips made during a day suggest more activities.

Travel distance and mode of transportation are indicators for the spatial distribution of this activity pattern. The means of transportation and travel distance have direct implications for economic, social, and environmental costs of transportation. External costs of travel, such as air pollution or traffic fatalities are directly related to automobile use and travel distance by automobile. Therefore daily travel distance overall, daily travel distance by car in particular, and mode choice are explicitly modeled in the next three chapters.

The number of trips is not as directly related to the external costs of travel as mode choice and travel distance. For example, multiple non-motorized trips will have a smaller impact on externalities than one car trip. Therefore the number of trips alone is not necessarily a useful measure for externalities of travel. Nonetheless, the trip rate per person per day is an important indicator for daily activity patterns of individuals and will be analyzed in this chapter.

Compared to the high level in variability of mode choice and trip distance across OECD countries, there has been relatively little variability in the average number of trips per person per day. In fact, the average number of trips per person has been found to be broadly stable across OECD countries (Schafer, 1999). Higher incomes and faster modes of transportation (mainly automobiles) allow farther daily travel distances; but trip rates only grow marginally with increasing income (Knoflacher, 2007; Schafer, 1999). Nonetheless differences existed between countries. Compared to poorer countries, individuals in higher income countries made more trips per day and devote a higher share of their trips to purposes such as shopping, meeting friends, or seeing a doctor. Knoflacher (2007) argued that the number of trips per person per day has been almost constant in OECD countries over the last 100 years. In his view, the only major change over time has been an increasing share of trips by automobile and growing trip distances—while the number of trips per person was almost stable.

Other studies showed that there was considerable variability in number of trips within countries, regions, and socioeconomic and demographic groups (Schafer 1999, Handy 1996, Boarnett 2001). For example, Crane (2000) and Handy (1996) found that individuals in higher population density and more mixed land use areas in the U.S. made more and shorter trips than individuals in low density areas.

Table 7.1 Descriptive Statistics for Two Transformations of the Dependent Variable Trips per Person per Day

	Germany						**U.S.**					
	Mean	*Median*	*Std*	*Min*	*Max*	*N*	*Mean*	*Median*	*Std*	*Min*	*Max*	*N*
Number of Trips	3.3	3.0	2.9	0	106	53,500	4.1	4.0	2.9	0	36	60,282
Number of Trips (<12)	3.2	3.0	2.3	0	12	53,214	4.0	4.0	2.7	0	12	59,659

As displayed in Table 7.1, in 2001/2002 Germans made 0.7 fewer trips per day than Americans (trip rates of 3.3 and 4.1). This difference at the aggregate level is surprising and could be related to higher incomes in the U.S. However, the findings of other studies cited above would suggest similar trip rates in both countries, or even a higher trip rate in Germany, due to shorter average trip distances and increased trip rates for these short trips (Crane, 2000; Crane & Chatman, 2003; Handy, 1996; Schafer, 1999)

The higher rate of trips in the U.S. was definitely not related to more actual trips originating from the home, as both Germans and Americans left their homes precisely 1.4 times per day. A disaggregate analysis by trip purpose, time of day and weekday, spatial development patterns, as well as socioeconomic and demographic factors can help explain the aggregate difference in trip rates. The following sections will investigate the influence of such factors on individual trip rates.

7.1 Trip Purpose

A look at the average number of trips per person by trip purpose showed that Americans made more personal and shopping trips and served passengers[99] for slightly more trips per day than Germans (Table 7.2). First, a higher rate of shopping trips in the U.S. could be explained by higher disposable incomes and lower saving rates in America than in Germany. Second, the lack of alternative modes of transportation and spread out development patterns in the U.S. could help explain the increased need to make trips for the purpose of bringing a passenger to a destination there compared to Germany. In Germany, car-less and individuals without driver's license could more easily get around by bike, on foot or by transit. Third, the main difference between the countries, however, was the number of private trips. These trips included meeting friends, going to church, or doctor's visits (see Table 7.2). There is no theoretical explanation why Americans would

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[99] E.g. bringing a passenger to a destination.

participate in more private activities than Germans. Schafer (1999) found the same phenomenon in a review of aggregate travel behavior statistics in OECD countries, but did not offer any convincing explanations.

Table 7.2 Number of Trips per Person per Day by Trip Purpose

	Number of trips per Day		Difference (USA - D)	% Difference
	Germany	USA		
Work/Work related	0.8	0.8	0.0	0%
Schooling	0.2	0.2	0.0	0%
Recreation	1.0	1.0	0.0	0%
Shopping	0.6	0.7	0.1	14%
Private	0.4	0.8	0.4	49%
Serve Passenger	0.3	0.4	0.1	30%
other		0.1	0.1	
Total	3.3	4.1	0.7	18%

7.2 Time of Day and Weekday

A look at the distribution of trips during weekdays and weekends (Saturday and Sunday) showed that German and American travel behavior was very similar. In Exhibits 7.1 and 7.2 the horizontal axis shows the time of day and the vertical axis displays the percentage of trips made during a given hour of the day. For both countries, the largest share of trips were during the morning and evening peak periods for weekdays—both indicating work commutes in the morning and late afternoon (6-9 a.m. and 3-6 p.m.). Peak periods in the U.S. were more pronounced than in Germany, which was consistent with a higher labor force participation rate in the U.S. The afternoon peak was more pronounced in both countries than the morning peak, consistent with expectations since more non-work related trips were also made in addition to the afternoon commute.

The peak travel period during the weekend was around noon for both countries. Interestingly, the weekend peak travel period was more pronounced than the weekday peaks. One would expect a more homogenous and spread out trip pattern on weekends, as there were fewer firm work related time commitments. Therefore individuals could freely choose their travel times on weekends and potentially avoid peak trip times. Overall, Americans made a higher share of their trips during the weekend than Germans (27.5 percent vs. 23.5 percent), which may be explained by later retail business hours in the U.S. In Germany, stores were required by law to stay closed on most Sundays.

Exhibit 7.1Percent Distribution of Trips by Start Hour on Weekdays and the Weekend in Germany

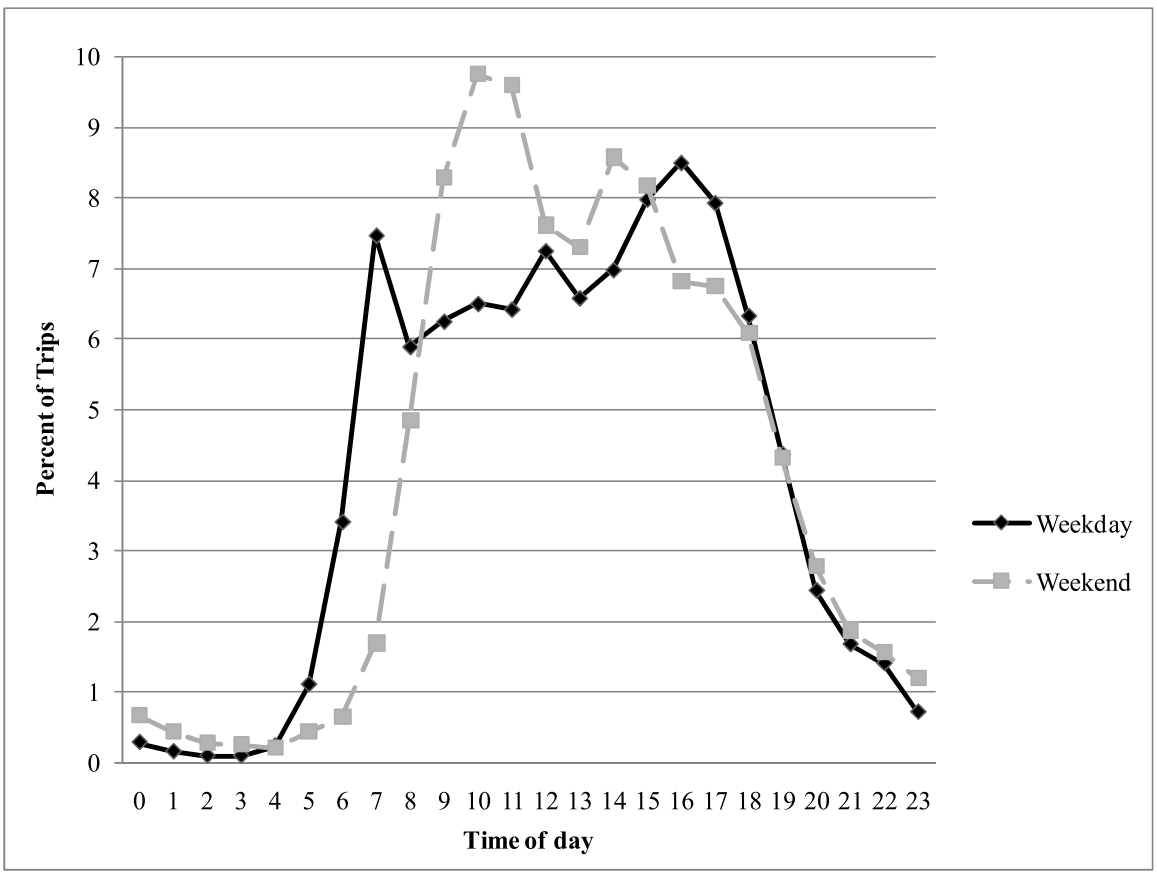
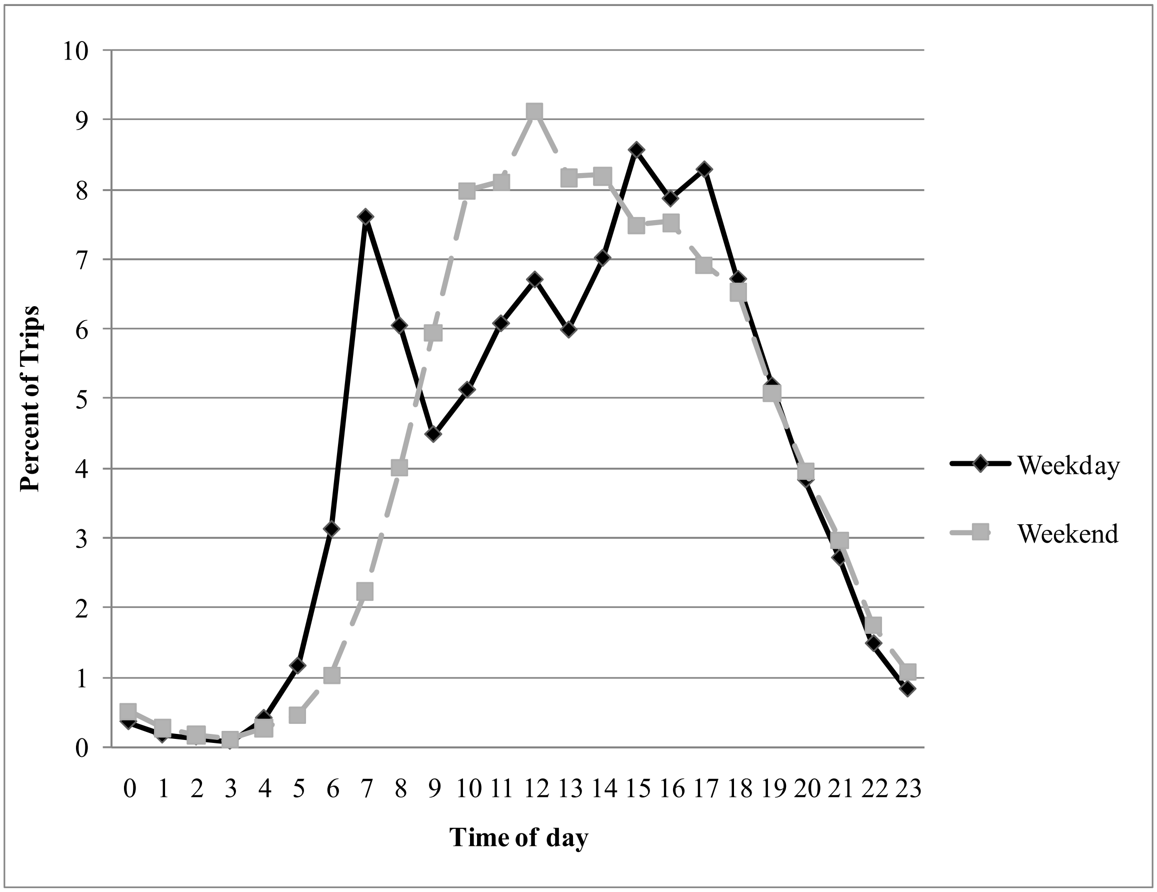


Exhibit 7.2 Percent Distribution of Trips by Start Hour on Weekdays and the Weekend in the U.S.



7.3 Spatial Development Patterns and Transit Access

There was only slight variability in trip rates by transit access and spatial development patterns within each country. For all categories of these independent variables however, Americans made more trips than Germans.

In both countries, individuals living within 400m of a transit stop made slightly fewer trips per day than the average: 3.9 trips compared to 4.1 in the U.S. and 3.2 trips compared to 3.3 trips in Germany. Furthermore, in Germany the number of trips was almost constant across metropolitan area size categories. In the U.S., the average number of trips per person declined slightly with metropolitan area size (from 4.1 in smaller metro areas to 3.9 in the largest agglomerations).

Exhibit 7.3 Average Number of Trips per Day by Density Category

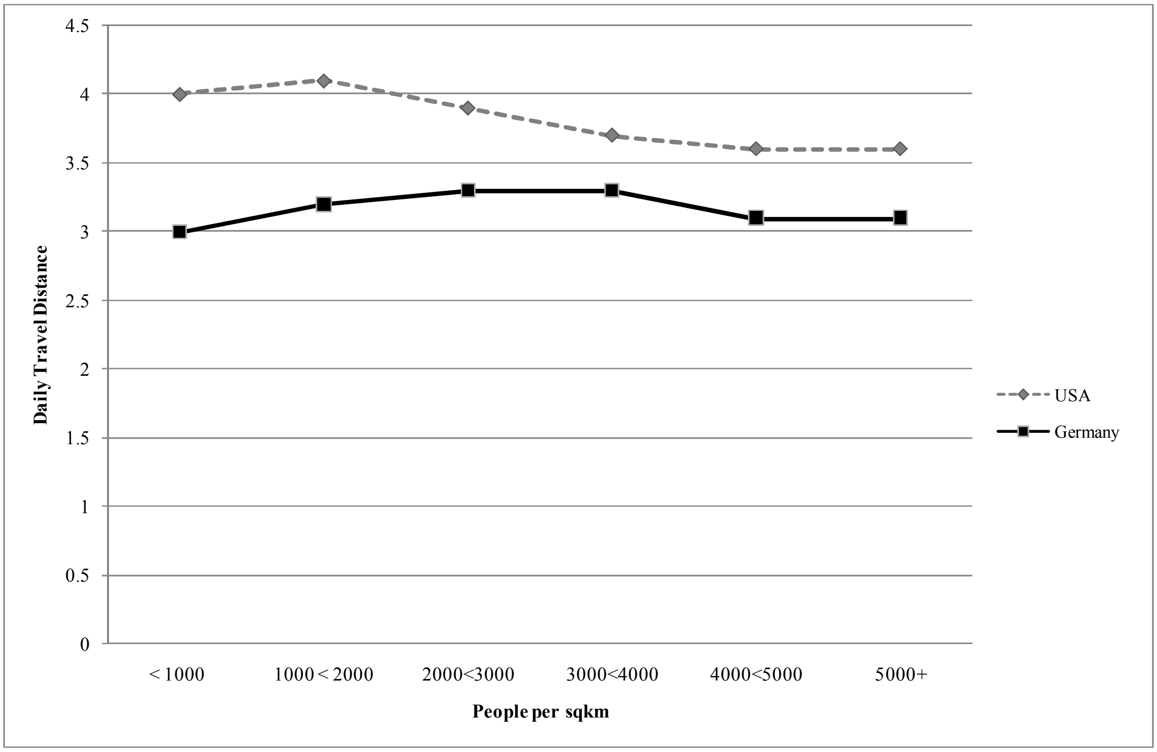


Exhibit 7.3 shows that in the U.S., the average number of trips declined when population density increased, with 3.6 trips per person in the densest settlements compared to 4.1 trips per person in the lowest density areas. In Germany, the number of trips first increased with population density and then declined. Individuals in the density category 3000 to 4000 people per km^2 made the most trips. Additionally, in Germany the number of trips declined with increasing mix of land uses, while the U.S. data did not show a pattern in number of trips across mix of land use categories. Some readers might think that these bivariate relationships might be mostly determined by household income. They would argue that in both countries, poorer households lived closer to transit stops and in denser areas resulting in lower trip rates there. Controlling for income, however,

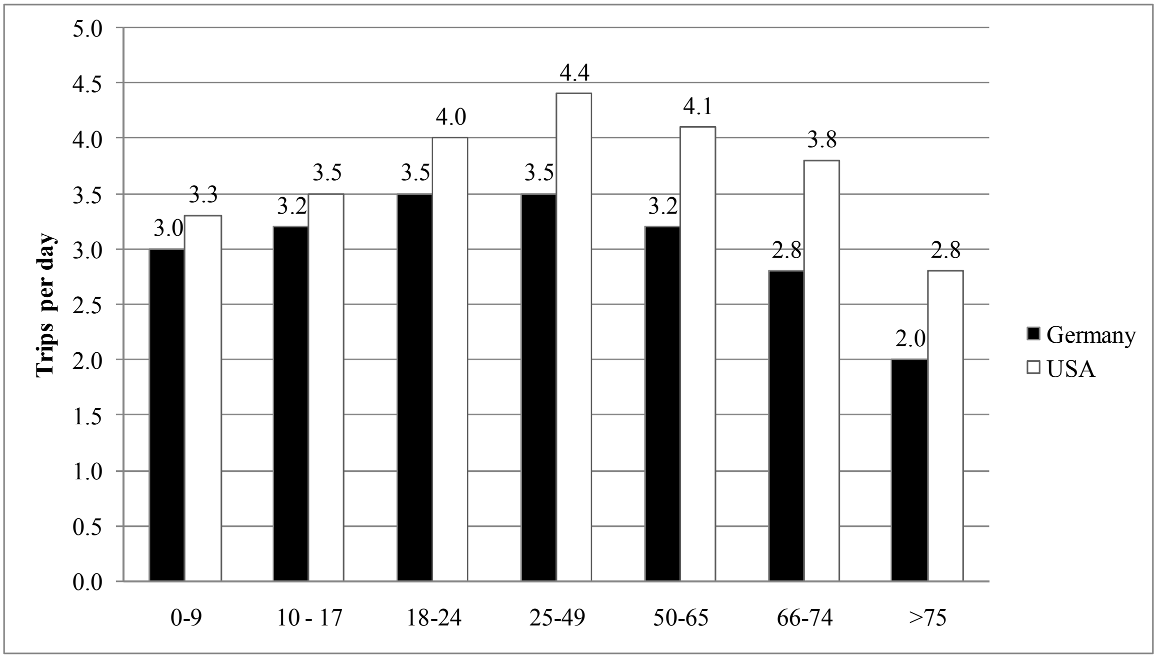
the relationships of transit access, spatial development patterns, and trip rates were the same as presented for the full samples above.

7.4 Socioeconomic and Demographic Factors

There was considerable variability in number of trips across age categories in both countries. In all age categories Americans made more trips than Germans. Although the expected trends held in both countries, Americans between 66 and 74 made more trips and participated in more activities per day than the most mobile age categories in Germany. This was surprising as most 66 to 74 year olds were retired while individuals in the most mobile age category in Germany were at working age. Participating in the labor force should, everything else equal, added two trips per day—one to and one from work.

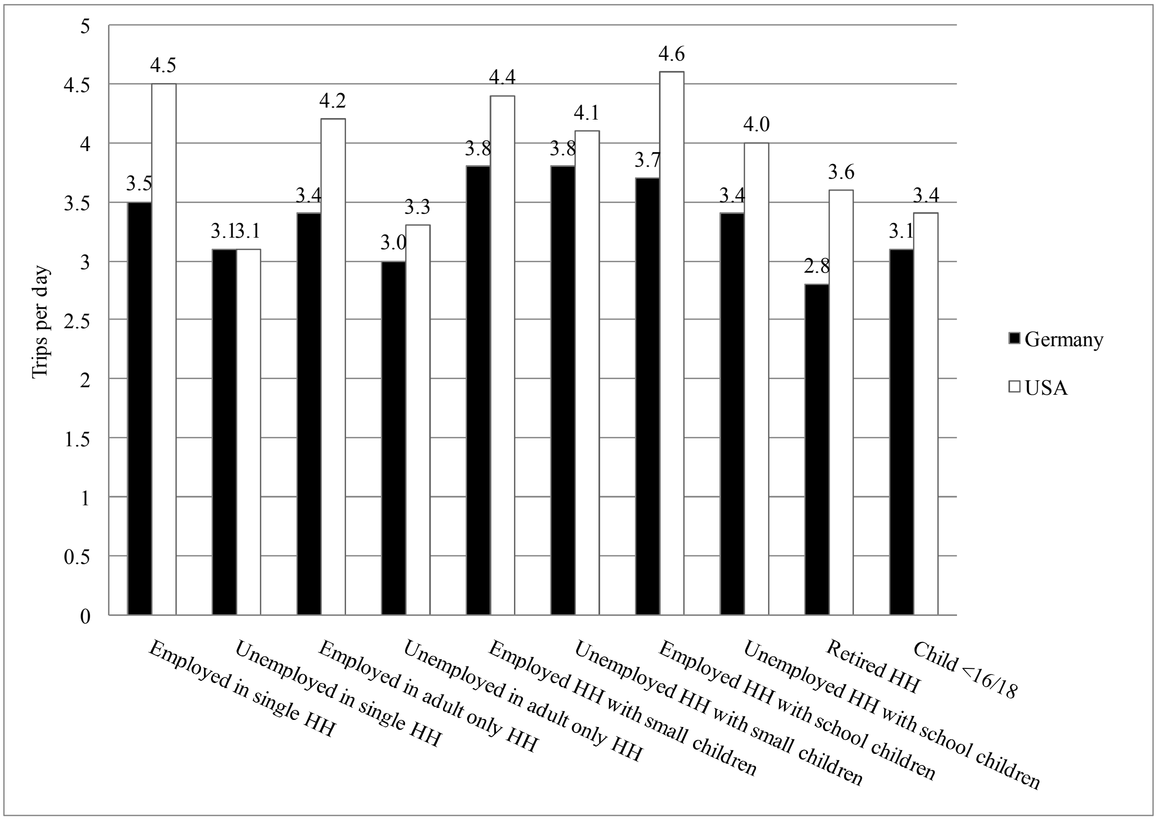
The difference in number of trips of the oldest age category and the most mobile age group was slightly more pronounced in Germany than the U.S. (43 percent fewer trips compared to 36 percent). The number of trips per person in the oldest age categories in Germany was also considerably lower than in the U.S. This might be explained by differences in socialization and timing of motorization. Germans in that age category were socialized in a society without the automobile and during the economically depressed post-WWII years. Many of them did not hold a driver's license and the experience of the years during and after the Second World War made them more economical than subsequent age cohorts, who grew up in more affluence.

Exhibit 7.4 Average Number of Trips per Person per Day by Age Group



Age alone could not explain differences in travel; household structure and employment status also played an important role. Exhibit 7.5 shows that employed individuals in general made more trips per day than individuals who were unemployed or not in the labor force. Adults in households with children were more mobile than adults in households without children. Retirees in the U.S. made almost as many trips as Germans in the most mobile household life cycle categories.

Exhibit 7.5 Number of Trips per Person per Day by Household Composition and Employment Status



In both countries, individuals with higher incomes and greater access to a car made more trips per day. In Germany, the number of trips ranged from 2.6 for individuals in households with 0.5 and fewer cars per household member at driving age to 3.6 trips for individuals in households with1.5 and more cars per household member at driving age. In the U.S., the trip rates were higher for all car ownership categories: 2.9 (<0.5 cars) and 4.3 (>1.5cars). The number of trips for the lowest and highest income quartiles was 2.9 to 3.5 in Germany and 3.5 to 4.3 in the U.S. Interestingly, the highest income quartile in Germany and the lowest income quartile in the U.S. made 3.5 trips per day.

7.5 Summary

A short overview of trip rates has shown that Germans make 18 percent fewer trips per day than Americans. Higher trip rates in the U.S. than in Germany were found for all independent variables and within all sub-groupings of transportation policy, spatial development patterns, socioeconomic, and demographic factors. Americans participated in more out of home activities and made more trips than comparable Germans.

General theories about the relationship of socioeconomic variables and number of trips held true within both countries. For example: employed individuals traveled more than the unemployed; and the elderly traveled less than mid-age respondents. Theories for spatial development patterns were not confirmed by the statistics presented above. Theories suggest an increasing trip rate with higher population density and more mix of land uses; in these datasets however, they were either unrelated or the trip rate decreases with increasing density and mix of land uses. This might be mitigated by income, however. As expected socioeconomic variables such as age played the greatest role in explaining differences in number of trips.

The number of trips was not explicitly modeled in this dissertation as the connection to externalities is less evident as for mode choice, total daily travel distance, and travel distance by car. Models for the number of trip variables would have to rely on Poisson or Negative Binomial regressions to capture the discrete count nature of these data. Due to the rigid assumption of a Poisson regression, the Negative Binomial might be the most likely candidate for a multivariate model (Freese & Long, 2006). The next three chapters will describe and analyze total daily travel distance, daily travel distance by car, and mode choice in detail.

8 Modeling Daily Travel Distance

For the first multivariate analysis, Ordinary Least Squares (OLS) regressions were estimated. Daily travel distance was regressed on transportation policies, spatial development patterns, socioeconomic and demographic variables, and proxies for macro-economic differences and culture. The units of analysis were individuals who made a trip on the travel day—excluding individuals who stayed at home. It could be argued that some explanatory variables not only influence travel distance, but also affect the decision to travel or not on a given day. For example, school children might be most likely to make a trip every day of the week, as they are required to attend school. The elderly, once retired, might not have such a firm daily commitment. As a result children might be more likely to make a trip on a travel day compared to the elderly. Trip distances on Sundays might be the same as during the week, but the probability of individuals staying at home and not making a trip at all may be higher on Sunday compared to the rest of the week.[100]

If this were true, alone estimating a regression for travel distance among the respondents who were traveling that day could lead to inefficient and biased estimates, due to sample selection bias. Therefore a two-stage Heckman Selection Model (HSM) was estimated modeling the decision to take a trip in the first stage and the distance traveled in the second stage. This served as a control for sample selection bias, and more

[100] An alternative modeling approach would include non-trip makers in the sample with the value of 0 as travel distance. Such a set of models was also estimated and results are provided in the appendix. All coefficients have the same signs and about the same magnitude, compared to the models presented in this chapter. As expected the variables of age and whether a person has a valid driver's license or not show slightly stronger coefficients in both countries. Additionally, the variable Sunday is statistically significant, which is not the case in models on distance alone.

accurately represented the trip decision making process, which consists of the two sequential decisions: to make a trip; and how far to travel.

8.1 Description of Univariate Distributions and Bivariate Relationships

8.1.1 The Dependent Variable

In Germany total daily travel distance ranged from 0.1 to 5722km, with a mean of 43.2km and a median of 18km. Travel distance in the U.S. ranged from 0.2km to 11344km, the mean was 74.5km and the median is 40km. Both distributions were skewed to the right with 95 percent[101] of all daily travel distances in Germany and the U.S. shorter than 200 kilometers (125 miles). A skewed distribution of the dependent variable would cause problems for a multivariate regression. First, outliers in the tail of the distribution would likely drive the results because of the influence they have on the slope of the regression line (an effect known as leverage). Second, outliers in the dependent variable might produce heteroskedastic errors. This would violate one of the assumptions of multiple regression analysis and could lead to inefficient estimators (Kohler & Kreuter, 2006).[102] This dissertation evaluated and compared coefficients and their statistical significance. Therefore, leverage and heteroskedasticity could be serious problems.

Two common solutions exist: (1) taking the natural logarithm of the dependent variable to achieve a more normal distribution or (2) eliminating extreme cases from the analysis (Kohler & Kreuter, 2006). Both approaches were tested and two sets of models were estimated: one with a logarithmic dependent variable and one with a truncated

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[101] 96.2 percent for Germany and 93.8 percent for the US.
[102] The large dataset on the other hand can help increase the statistical significance of the variables.

dependent variable. The second alternative, while reducing the sample size somewhat, was a logical approach, as (a) daily travel distances of more than 200km were most likely not usual travel days of an average person and (b) the interpretation of the results remained unchanged.[103]

Additionally, every transformation results in distortion of the data. A logarithmic transformation compresses larger values more than small values. For example, the difference of the logarithm of one and two is much larger than the difference between log of 101 and 102. This potentially can—and in fact did—lead to interpretational problems. The descriptive statistics for the original and transformed variable are shown in Table 8.1 below.

Table 8.1 Descriptive Statistics for Three Transformations of the Dependent Variable Total Kilometers of Daily Travel per Person

	Germany						USA					
	Mean	*Median*	*Std*	*Min*	*Max*	*N*	*Mean*	*Median*	*Std*	*Min*	*Max*	*N*
Distance travel day	43.2	18.0	93.3	0.1	5722	45,698	74.5	40.0	189.7	0.2	11344	52,627
Distance on travel day (<200km)	29.9	17.0	34.4	0.1	200	43,989	49.1	36.0	43.9	0.2	200	49,358
LN (distance on travel day)	2.8	2.9	1.4	-4.6	8.4	45,698	3.5	3.7	1.3	-1.7	9.3	52,627

8.1.2 Explanatory Variables

The descriptives for the explanatory variables presented below are for individuals who traveled by car, transit, bike, or on foot on the travel day. Only individuals with total daily travel distances of less than 200km on the travel day were included for the reason just explained.

[103] Traveling more than 200km a day would require a considerable amount of time spent on the road. Even by car, the fastest mode of transportation in both countries, 200km of travel would mean over three hours of daily travel. Average car trip speeds in the U.S. are 42 km/h and 33km/h for Germany. At these speeds a daily travel distance of over 200km would imply a daily travel time of more than four hours and 40 minutes in the U.S. and more than six hours in Germany. Even assuming an average speed of 60km/h would yield about three hours of daily travel.

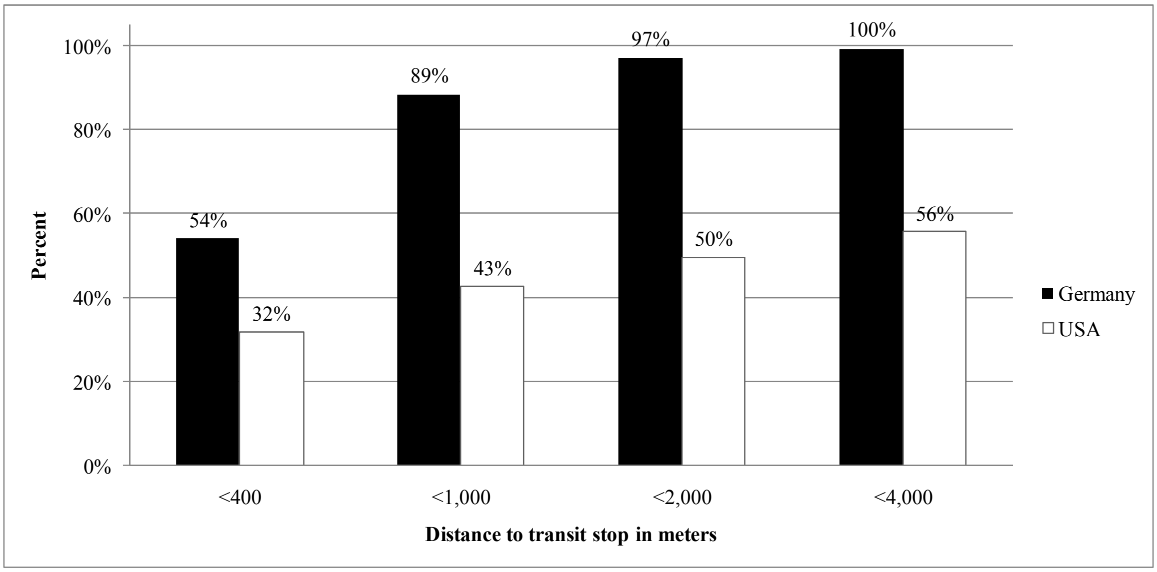
8.1.2.1 Policy Variables

Transit Access

Exhibit 8.1 below shows that more Germans lived within closer range of a transit stop than Americans. Most recent studies assumed that 400 meters (approx. 1/4 mile) was a walkable distance to transit, which was assumed to significantly increase transit use and levels of walking. It is also possible that individuals residing farther away still use transit, but the effect might decline with increasing distance. Two dummy variables for distance to a transit stop were used to capture this effect. The first variable indicated if a household was within 400m of a transit stop. The second variable specified if a household was between 400 and 1000m of a transit stop. With increasing distance to a transit stop total daily travel distance was expected to increase.

This measure did not include the level of transit service (e.g. number of vehicle kilometers of transit supplied to that stop), but given the data, this variable could serve as a proxy for overall policies towards public transportation.

Exhibit 8.1 Access to Public Transportation: Household Distance to a Transit Stop (Cumulative, in Meters)

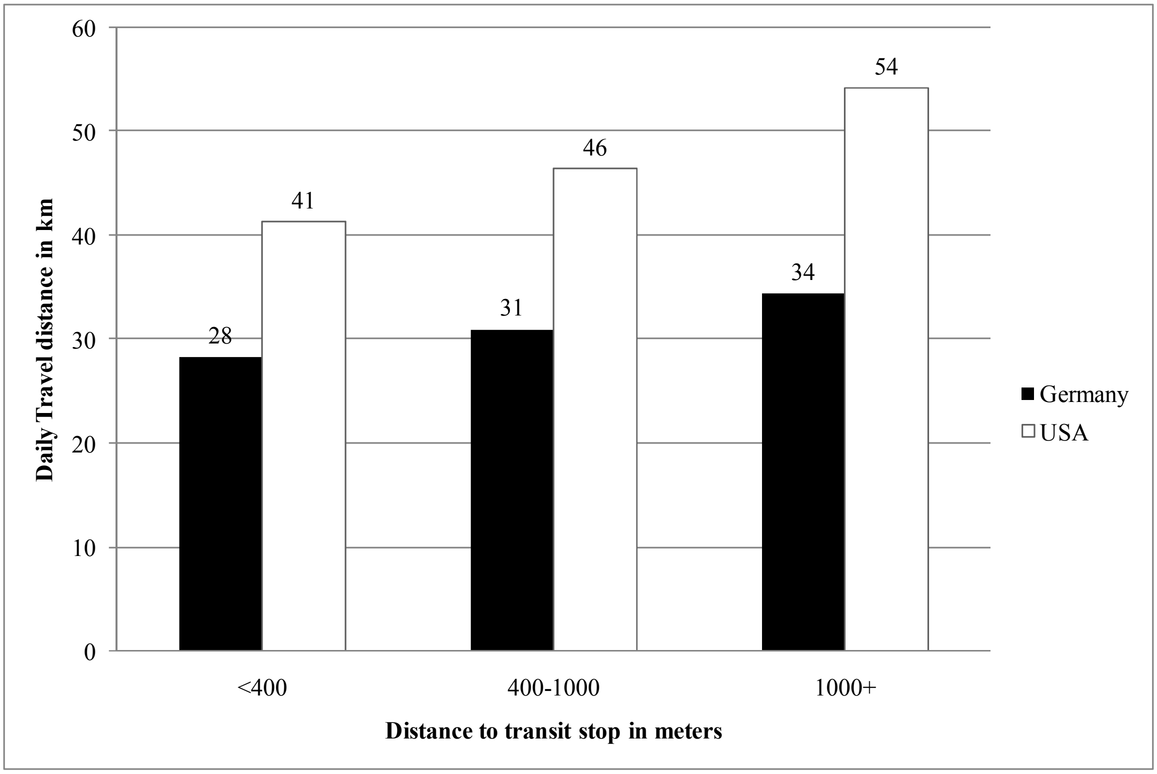


(Data: all respondents traveling fewer than 200km per day)

Distance to Public Transportation and Distance Traveled

Exhibit 8.2 below shows that easier access to public transportation was related to shorter average daily travel distance in both countries. In the U.S., individuals who lived within 400m of a transit stop traveled 28 percent less km (54km vs. 41km) per day than individuals residing more than 1km away from a transit stop. This difference was smaller for Germany: only 18 percent (34km vs. 28km).

Exhibit 8.2 Average Kilometers of Daily Travel by Household Distance from Transit Stop



(Data: all respondents traveling fewer than 200km per day)

8.1.2.2 <u>Spatial Development Patterns</u>

Metropolitan Area Size

Population served as indicator for metropolitan area size for the U.S. and Germany. In contrast to the U.S., where MSAs were defined by the U.S. Census Bureau, there were no similarly defined metropolitan areas for Germany. The German Federal Ministry of Spatial Development (BBR) informally compiled a classification of MSAs for Germany, which was similar to the U.S. and was provided to the author. The distribution of the respondents across metropolitan areas by size category was similar (see Table 8.2 below).

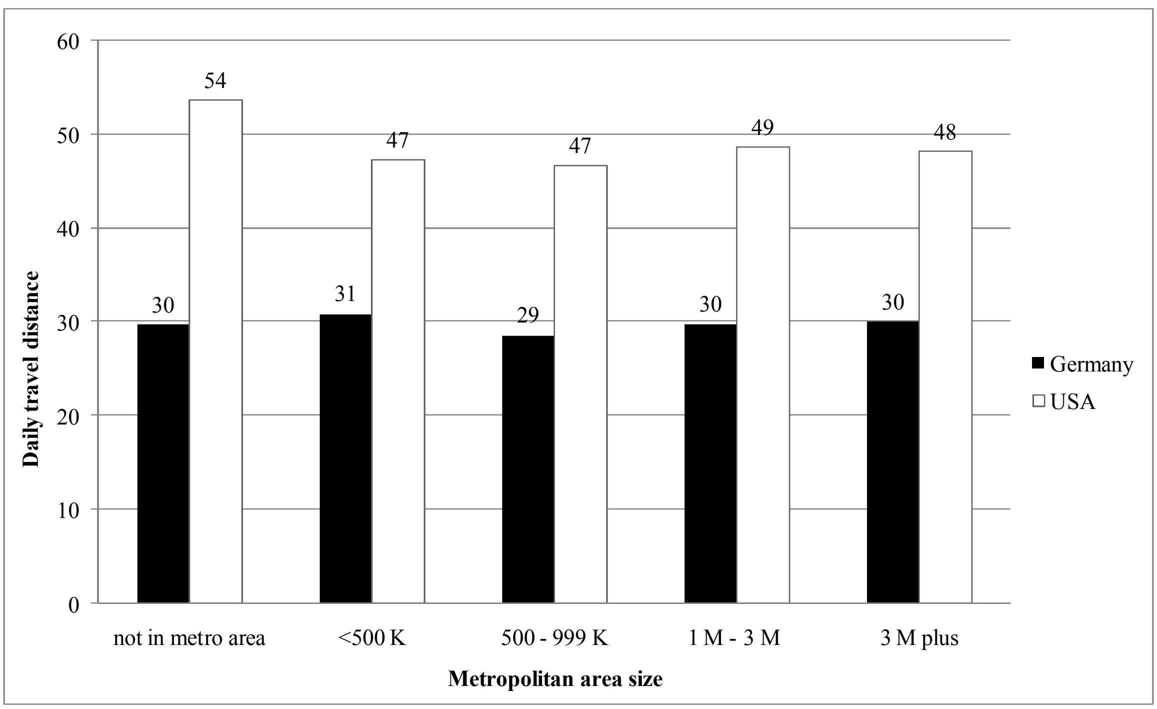
Table 8.2 Percentage Distribution of Respondents by Metropolitan Area Size

Metropolitan area size	Germany	USA
Not in metropolitan area	27%	22%
Up to 500,000 inhabitants	13%	16%
500,000 to 999,999 inhabitants	12%	8%
1 million to 2,999,999 inhabitants	21%	22%
3 million and more inhabitants	27%	32%

(Data: all respondents traveling fewer than 200km per day)

The data for this analysis did not show significant differences in daily travel distance across metropolitan area size categories (see Exhibit 8.3 below). Furthermore, metropolitan area size was correlated with the other spatial development variables—thus causing multicoliniarity problems in the analysis. Metropolitan area size was therefore eliminated from the distance of travel analyses.

Exhibit 8.3 Average Daily Kilometers of Travel by Metropolitan Area Size Category



(Data: all respondents traveling fewer than 200km per day)

Population Density

Population density would ideally be measured at the neighborhood level and would only include land area settled or used for transportation infrastructure. This would capture the exact settlement density around a residence. Population density for this statistical analysis was measured as people per census tract land area in the U.S. and as people per land area used for settlements and transportation infrastructure in Germany. The U.S. measure was more precise at the census tract level, but included unsettled land within census tracts. The German measure was on the municipal level, but only included land area used for transportation infrastructure and settlements. Even though both measures could ideally be more precise[104] and more comparable, they were the best available data.

The average population density for Germany was 2,549 people per km^2, compared to 1,457 in the U.S. The distribution was much more homogeneous for Germany than the U.S. The U.S. distribution had some extreme outliers to the right, potentially related to high population densities in Manhattan and downtown Chicago. Only 1.8 percent (853 individuals) of all U.S. respondents who traveled less than 200km per day lived at population densities of more than 10,000 people per square kilometer. Eliminating these extreme values yielded an average population density of 1,084 people per km^2 for the U.S. (see density two in Table 8.3 below). The regression results below included the truncated density (density 2) as an interval ratio variable.

[104] E.g. excluding not-settled land area in the U.S., and greater detail around the household location in Germany

Table 8.3 Descriptive Statistics of Two Versions of the Variable Population Density

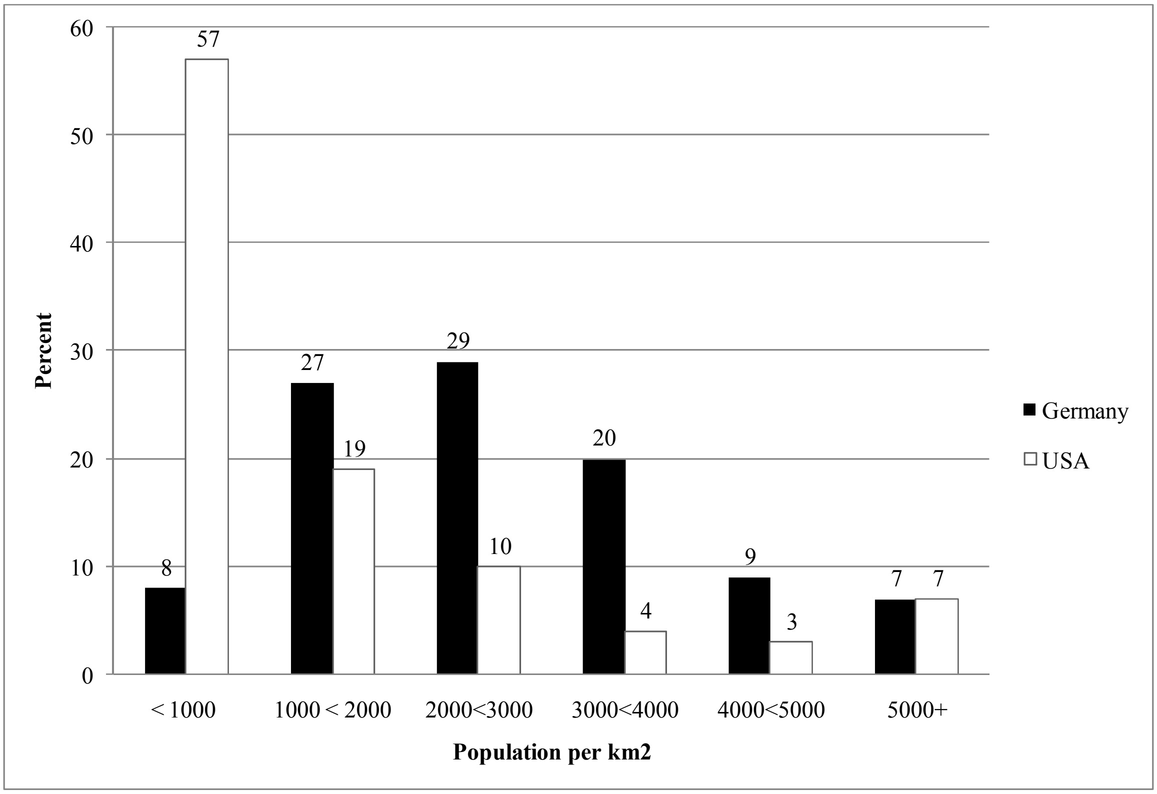
	Germany					USA				
	Mean	Median	Std	Min	Max	Mean	Median	Std	Min	Max
Density 1 (people per km^2)	2544	2411	1257	526	5678	1461	567	3655	0.01	76222
Density 2 (people per km^2)	2544	2411	1257	526	5678	1078	536	1442	0.01	9980

(Data: all respondents traveling fewer than 200km per day)

Exhibit 8.4 shows the population distributions across density categories. Close to 80 percent of U.S. respondents lived at population densities of 2,000 people per km^{2}or less, compared to only 35 percent of Germans. The distribution for Germany was more homogeneous than the skewed U.S. distribution. Transforming this variable into a logarithmic scale to overcome the skewness was not successful, as the logarithmic transformation of the originally left skewed variable resulted in a right skewed distribution. Therefore this variable was used in its original form, but truncated at 10,000 people per km^2 for the multivariate analysis.

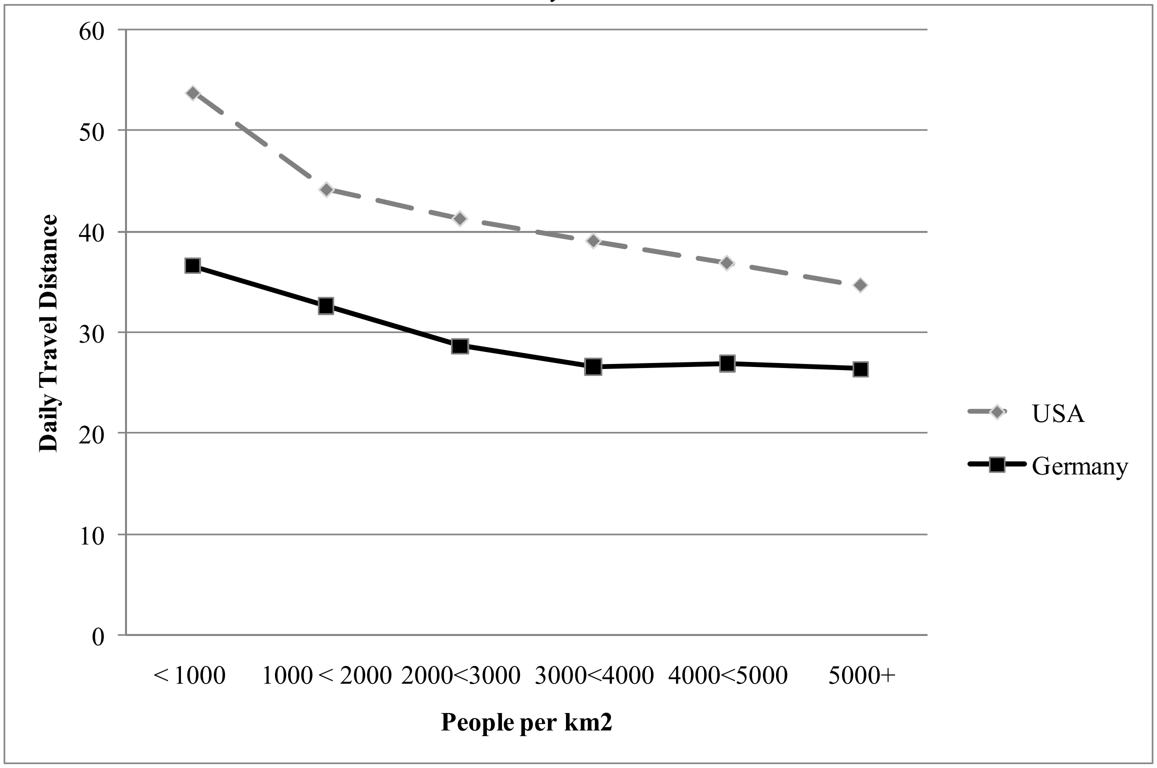
Exhibit 8.5 shows that population density was related to travel behavior in both countries. The greater the population density was, the shorter was the total daily travel distance per person. Interestingly, Americans in the highest population density category traveled about the same distance per day as Germans in the lowest density categories. Clearly, density played a role in explaining daily travel distance in both countries, but on different levels. Across all population density categories, Americans traveled about 50 percent more kilometers than their German counterparts living at similar population densities.

Exhibit 8.4 Distribution of Respondents by Population Density Categories in Germany and the U.S.



(Data: all respondents traveling fewer than 200km per day)

Exhibit 8.5 Average Kilometers of Daily Travel per Person per Day by Density Category in Germany and the U.S.



(Data: all respondents traveling fewer than 200km per day)

Mix of Land Uses

Mix of land uses was measured as a variable ranging from 0 to 1. A value of one indicated a balanced mix of households and work places, while a zero stood for almost no mix of work and housing uses. The mean of both countries' distributions was slightly higher than 0.3 (see Table 8.4 below). This was unexpected, as Germany was thought to have more mixed-use than the U.S. (Hirt, 2008). A closer look at the distribution reveals that the German distribution was more homogeneous than the U.S. distribution. The U.S. median for mix of uses was 30 percent lower than the median for Germany and 22 percent lower than the U.S. mean.

Table 8.4 Descriptive Statistics of the Variable Mix of Use

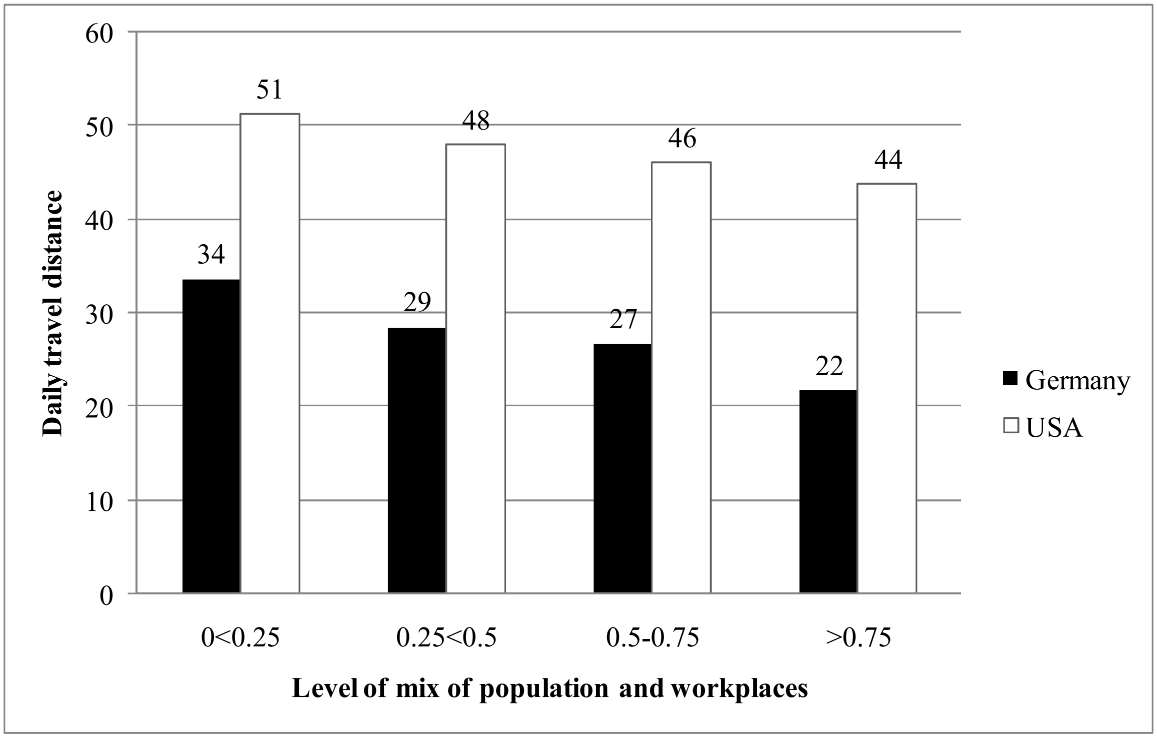
	Germany					USA				
	Mean	Median	Std	Min	Max	Mean	Median	Std	Min	Max
Mix of uses	0.34	0.35	0.2	0.03	0.8	0.32	0.25	0.2	0.01	1.0

(Data: all respondents traveling fewer than 200km per day)

Exhibit 8.6 shows that in both countries greater of mix of workplaces and population was related to shorter daily travel distances.[105] Similar to the findings for population density; while mixed land use had the same effect on travel distance, both countries were at quite different levels. Americans living in the highest mixed-use category traveled more kilometers a day than Germans in the lowest mixed-use category. In every land-use category however, Americans traveled between 50 percent and 100 percent more kilometers per day than Germans.

[105] For presentation purposes, the variable ranging from 0-1 is broken down into categories; it enters the regression as an interval ratio variable, however.

Exhibit 8.6 Average Kilometers of Daily Travel by Mix of Land-Use Categories



(Data: all respondents traveling fewer than 200km per day)

8.1.2.3 Socioeconomic and Demographic Variables

Descriptive statistics for socioeconomic and demographic variables are summarized in Table 8.5 below. Reported annual real household incomes in Germany ranged from $4,800 to $72,800 with an average income of $47,203. U.S. real household incomes ranged from $2,500 to $120,000 with an average income of $57,800. Median incomes were $43,600 for Germany and $52,500 for the U.S. The percentage of driver's license holders at driving age was slightly higher in the U.S. compared to Germany (92.4 percent compared to 86.1 percent). There was a higher percentage of households with small children and a lower percentage of retired households in the U.S. than in Germany.

Table 8.5 Descriptive Statistics of Socioeconomic and Demographic Variables

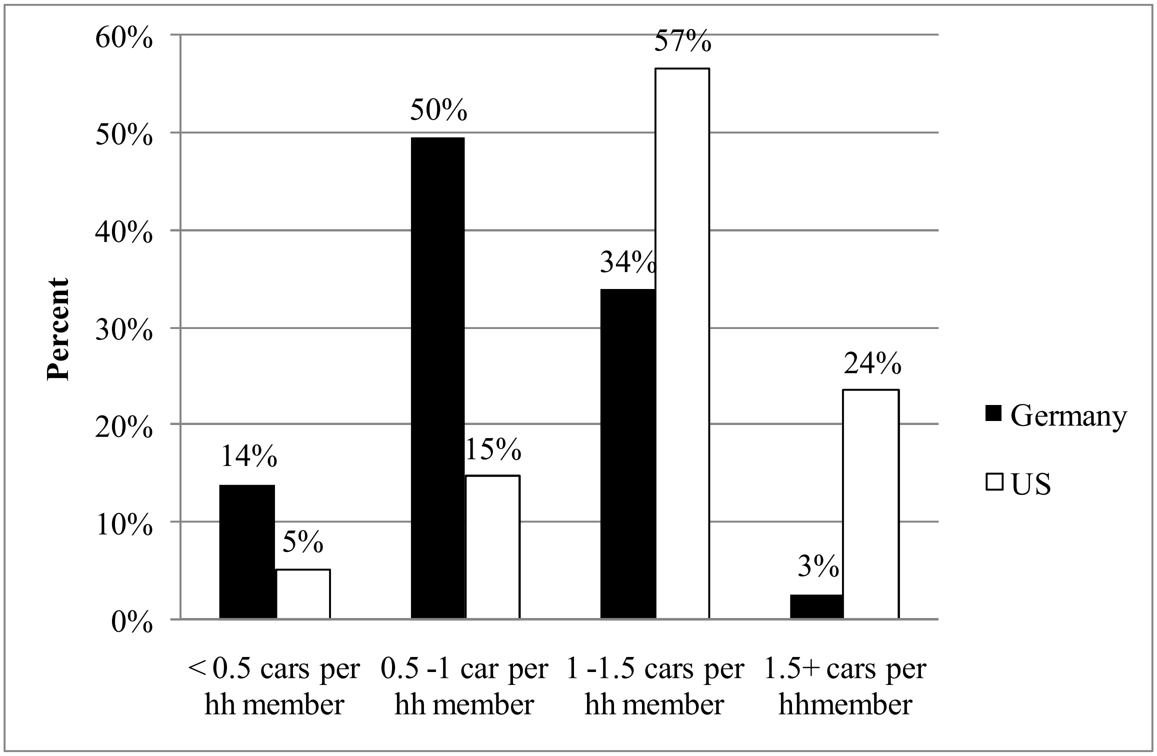
	Germany					USA				
	Mean	Median	Std	Min	Max	Mean	Median	Std	Min	Max
Cars per household member at driving age	0.7	0.5	0.4	0.0	4.0	1.1	1.0	0.6	0.0	4.0
Household Income										
Income (in $1,000)	47.2	52.5	17.6	4.8	72.8	57.1	43.6	33.5	2.5	115.0
% with income less than 25k	15.4%	n.a.				18.2%	n.a.			
% with income 25k to 55k	53.7%					42.1%				
% with income 55k plus	30.9%					39.7%				
Driver's license										
% with driver's license	68.1%	n.a				71.8%	n.a			
% with driver's license at driving age	86.1%					92.4%				
% male	49.2%	n.a				47.4%	n.a			
% employed	44.2%	n.a				51.5%	n.a			
% children	20.9%	n.a				24.2%	n.a			
Household life cycle										
Single household	3.9%	n.a.				5.2%	n.a.			
Couple, adults only household	20.1%					18.7%				
Household with small children	16.1%					23.4%				
Household with school children	35.4%					32.6%				
Retired household	24.6%					20.0%				

(Data: all respondents traveling fewer than 200km per day)

Car Ownership

For the multivariate analysis, car access was measured as cars per household members of driving age. In the U.S. there was an average of 1.1 cars per household member of driving age compared to 0.7 in Germany. Most U.S. respondents (81 percent) lived in households with more than one car per household member of driving age (see Exhibit 8.7 below). Only 37 percent of German households owned more than one car per household member of driving age.

Exhibit 8.7 Percent Distribution of Respondents by Number of Cars per Household Member at Driving Age

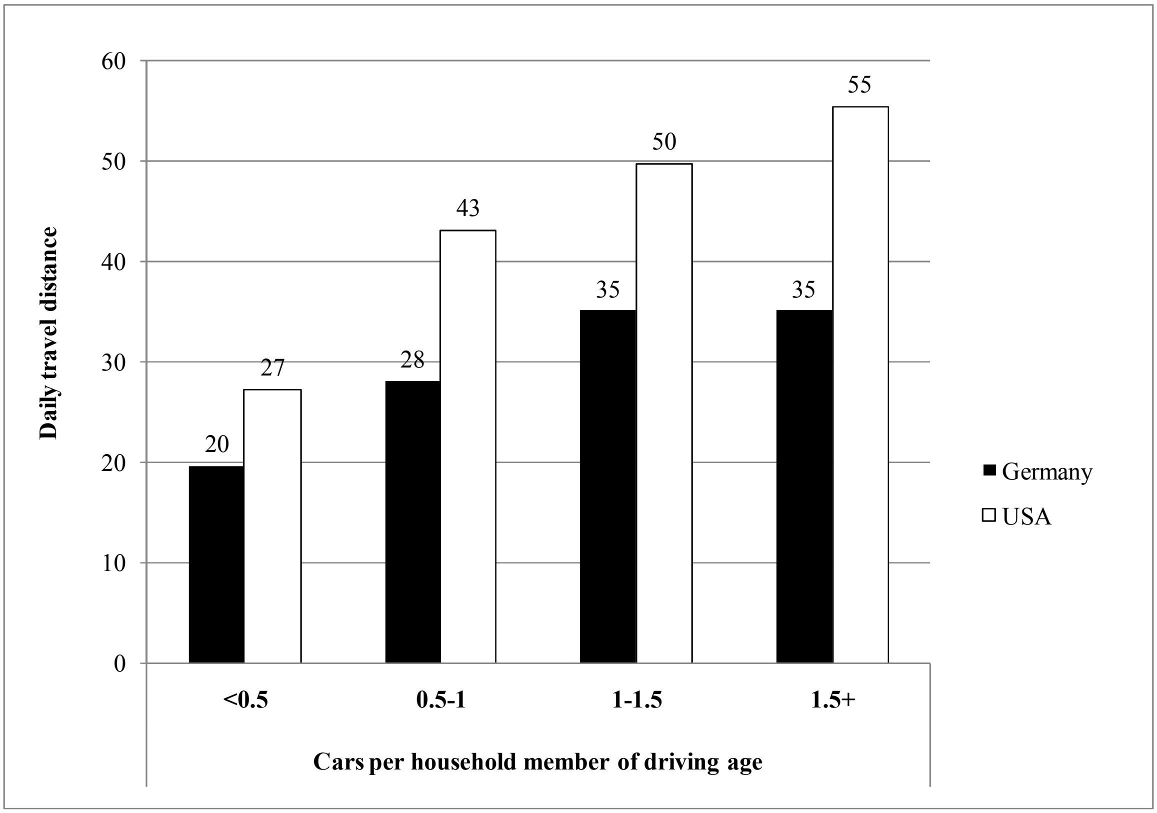


(Data: all respondents traveling fewer than 200km per day)

Cars per Household and Travel Distance

In both countries, easy access to an automobile was connected to longer daily travel distances. Causation might go in both directions (Schimek, 1997). First, households that had higher mobility needs tentatively owned more vehicles. Second, households who owned more vehicles traveled longer distances because of their ability to drive. In both countries, households with less than 0.5 cars per driver traveled about 50 percent fewer kilometers a day than households with 1.5 cars per driver (see Exhibit 8.8 below). Americans in households with 0.5 to one cars per household member still traveled more kilometers per day than Germans in households with more than 1.5 cars per household member.

Exhibit 8.8 Average Kilometers of Daily Travel by Number of Cars per Household Member of Driving Age

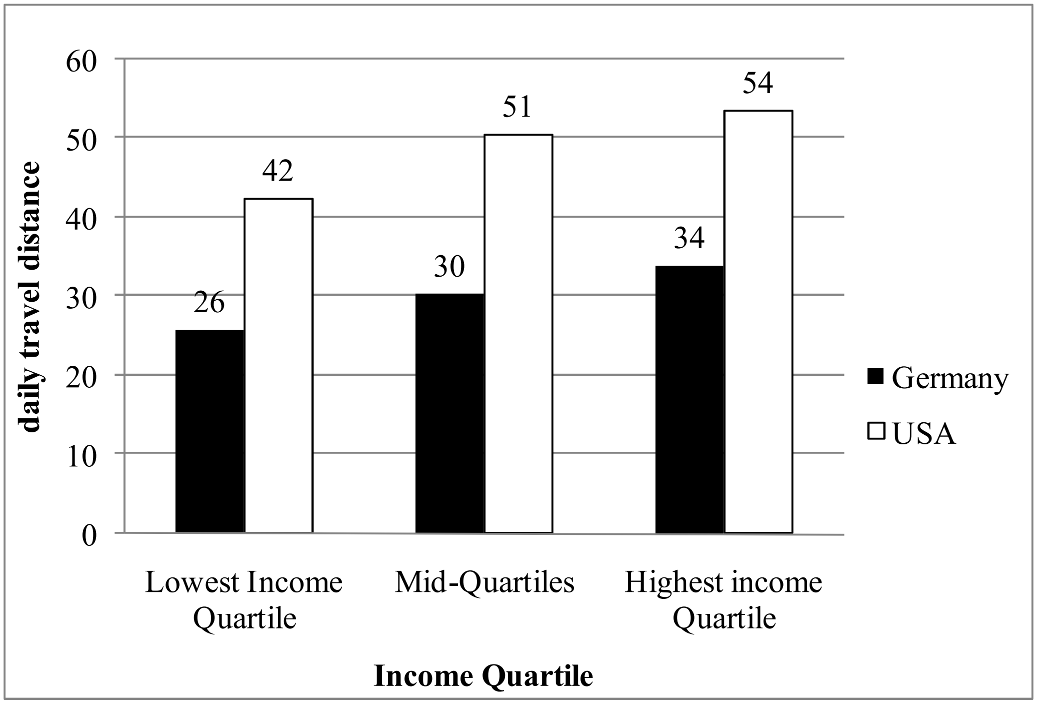


(Data: all respondents traveling fewer than 200km per day)

Household Income and Travel Distance

For graphical presentation of the bivariate relationship, households were grouped by income quartiles as shown in the graph below. The regression analysis included income as an interval ratio variable. In both countries, higher household incomes were related to longer daily travel distances. Similar to the observations with the spatial development patterns variables, the lowest income quartile in the U.S. traveled more kilometers per day than Germans in the highest income quartile (see Exhibit 8.9 below). Americans in the same income quartile as Germans traveled about 50 percent more kilometers per day. The difference of travel between the lowest and highest income quartiles was slightly larger in Germany than in the US: 33 percent more kilometers for the highest income quartile in Germany, compared to 31 percent in the U.S.

Exhibit 8.9 Average Kilometers of Daily Travel by Income Quartile



(Data: all respondents traveling fewer than 200km per day)

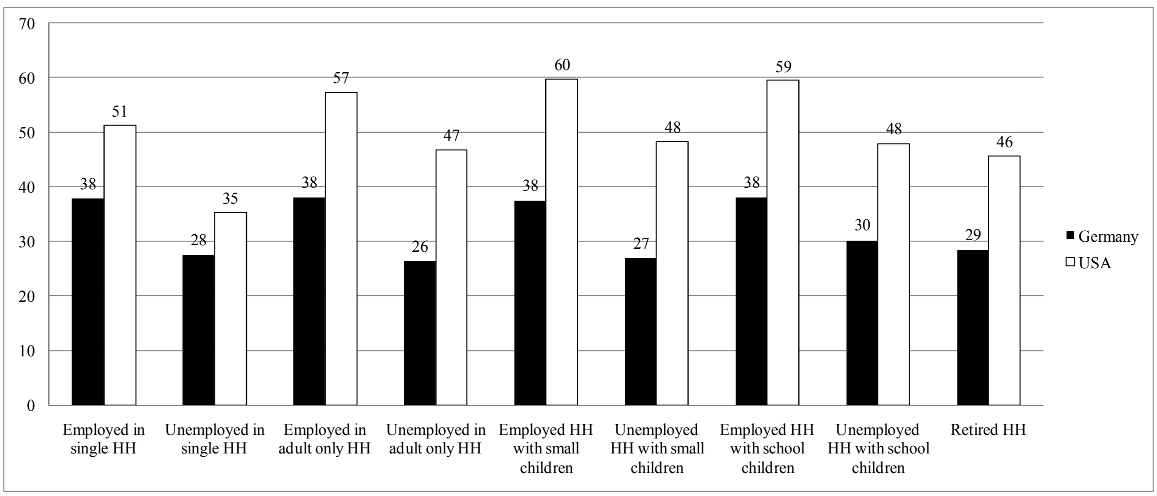
Travel Distance by Driver's Licensing, Gender, and Age

Not surprisingly respondents with a driver's license traveled more in both countries: 54 kilometers with a license and 34 kilometers without in the U.S. compared to 35 and 18 kilometers in Germany respectively. As expected, in both countries women traveled fewer kilometers per day than men. In the U.S. women traveled nine percent fewer kilometers than men (47.3 compared to 51.2km for men). In Germany women traveled 20 percent fewer kilometers than men (26.6km compared to 33.3km for men). Furthermore, children traveled fewer kilometers per day than adults. Interestingly, daily average travel distance for adult Germans (33km) was shorter than for children in the U.S. (35.5km).

Household Life Cycle, Employment and Travel Distance

Exhibit 8.10 shows that, for every household life-cycle category, unemployed individuals traveled less than employed individuals. In the U.S., employed adults in households with children traveled the greatest number of kilometers per day. In Germany employed adults in households with and without children traveled the most kilometers per day.

Exhibit 8.10 Average Kilometers of Daily Travel by Household Composition and Employment Status



(Data: all respondents traveling fewer than 200km per day)

8.1.2.4 Differences in Macro-Economy

As explained above differences in macro-economic conditions were difficult to measure on the level of the individual. The only variable available compared travel behavior on Sundays to weekdays. This was of course a very rough proxy for macro-economic differences. Germans traveled 28.8km on Sundays, compared to 30km on other days of the week. Americans also traveled slightly fewer kilometers on Sundays compared to other days of the week (48.2km on Sundays compared to 49.3km on weekdays). There was not much of a difference in kilometers traveled between Sundays and weekdays.[106] This variable might have been more relevant in explaining difference in the probability of making a trip in the Heckman Selection Model, however. It was included in the multivariate analysis as it made theoretical sense to control for macro-economic differences.

Proxy for other National Differences U.S. – Germany Dummy Variables

This variable simply identified German and American respondents (1=Germany, 0=US). The sample included 49.4 percent U.S. respondents and 50.6 percent German respondents. Americans traveled 49.1km per day compared to only 29.9km for Germans.

8.1.3 Bivariate Correlations

Table 8.6 below presents bivariate correlations among all variables included in the multivariate analysis. All bivariate correlations were statistically significant, which did not come at a surprise given the large sample size. Only a few independent variables were correlated higher than the absolute value of 0.3, and were indicated with an underscore. These correlations were found between car ownership, density, transit access, and the Germany dummy variable. These correlations suggest that households in denser areas had better transit access and owned fewer automobiles. Furthermore, Germans lived generally in denser settlements and owned fewer cars than Americans.[107] The

[106] But the likelihood to make a trip on a Sunday is lower in both countries. During the week 89 percent of Americans make at least one trip a day, compared to only 84 percent on Sundays. In Germany 89 percent of respondents make a trip on a weekday, but only 75 percent of respondents make a trip on a Sunday. While the Sunday/weekday distinction might not be able to help explain travel distance, it might help explain differences in the likelihood to make a trip between the two countries in the analyses of number of trips.

[107] The correlations between the independent variables are not considered high. One strategy to dissolve correlation among independent variables is to build factors of independent variables using factor analysis (or principal component analysis, a special case of factor analysis). Unfortunately, the correlated variables all fall into different categories of variables: transit access is a policy variable, population density relates to spatial development patterns, car ownership falls into socioeconomics and the Germany dummy variable measures culture. An attempt was made to reduce the number of independent variables via principal

correlations for the variable Sunday were very low (almost 0) for all variables and only two of its correlations were statistically significant at the 0.01 level.

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component analysis. Unfortunately, the variables from different categories fell into similar components (e.g. car ownership together with transit access and density). For interpretation purposes the author decided to leave the variables unchanged.

Table 8.6 Bivariate Correlations for Independent and Dependent Variables

	Distance Traveled	Transit Access <400	Transit Access 400-1000m	Density	Mix	Income	Car Access	Driver's License	Kid / teenager	with job in single HH	w/o job in single HH	with job in couple HH	w/o job in couple HH	with job in HH with child <6	w/o job in HH with child <6	w/o job in HH with child 6-16	retired HH	Male/ female	Sunday*
Distance Traveled	1.00																		
Transit <400	-0.14	1.00																	
Transit 400-1000m	-0.07	*-0.46*	1.00																
Density	-0.21	*0.40*	0.13	1.00															
Mix	-0.08	0.08	-0.01	0.09	1.00														
Income	0.14	-0.09	0.00	-0.10	-0.04	1.00													
Car Access	0.21	-0.23	-0.10	*-0.36*	-0.07	*0.28*	1.00												
Driver's License	0.21	-0.03	0.00	-0.04	0.01	0.05	0.11	1.00											
Kid / teenager	-0.15	-0.04	-0.01	-0.06	-0.03	0.06	0.08	-0.81	1.00										
with job in single HH	0.03	0.02	-0.02	0.03	0.04	-0.11	0.08	0.10	-0.11	1.00									
w/o job in single HH	-0.02	0.02	-0.01	0.04	0.02	-0.11	-0.05	0.02	-0.05	-0.02	1.00								
with job in couple HH	0.10	-0.01	-0.03	-0.04	0.00	0.12	0.06	0.21	-0.21	-0.08	-0.03	1.00							
w/o job in couple HH	-0.05	0.04	0.03	0.07	0.01	-0.04	-0.09	0.07	-0.12	-0.04	-0.02	-0.09	1.00						
with job in HH with child <6	0.09	-0.03	-0.01	-0.03	-0.01	0.04	0.04	0.16	-0.16	-0.06	-0.02	-0.11	-0.07	1.00					
w/o job in HH with child <6	-0.01	0.00	0.00	0.02	-0.01	-0.03	-0.03	0.07	-0.09	-0.03	-0.01	-0.07	-0.04	-0.05	1.00				
w/o job in HH with child 6-16	-0.01	0.01	0.02	0.01	-0.01	0.00	-0.04	0.07	-0.11	-0.04	-0.02	-0.08	-0.05	-0.06	-0.04	1.00			
retired in retired HH	-0.05	0.03	0.01	0.06	0.03	-0.19	-0.15	0.16	*-0.28*	-0.10	-0.04	-0.20	-0.12	-0.15	-0.09	-0.11	1.00		
Male/ female	0.06	0.00	0.00	0.00	0.00	0.03	0.03	0.04	0.03	0.01	-0.01	0.04	-0.04	0.04	-0.12	-0.07	-0.01	1.00	
Sunday*	0.00	0.00	-0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	1.00
Germany/USA	-0.24	0.23	0.28	*0.48*	0.05	-0.19	*-0.44*	-0.03	-0.06	-0.05	0.01	-0.10	0.13	-0.08	0.02	0.05	0.09	0.01	-0.03

if not inicated differently: all correlations significant at 0.01 level (two tailed)

*For variable Sunday: only correlations with transit distance, Germany/US dummy, and distance traveled are significant at 0.05 level (two tailed)

(Data: all respondents traveling fewer than 200km per day)

8.1.4 A Findings from Bivariate Analysis

Almost all variables had the expected relationships with the dependent variable. The only exception was size of the metropolitan area, which did not have an influence on daily distance traveled in this particular sample. For nearly all variables, the U.S. displayed greater distance of travel than Germany throughout the range of the distribution of the independent variables.

For some variables the greatest distance of travel in Germany was even less than the least distance of travel found for the U.S. For example, Americans in the lowest income quartile traveled 19 percent more kilometers per day than individuals in the highest income quartile in Germany. The expected theoretical relationship of longer travel distances with increasing incomes held true within both countries; but differences between the countries could not solely be explained by differences in income. Theory would lead us to expect that everything else equal, German individuals who were richer than American individuals would travel more; and that similarly wealthy individuals would display similar travel behavior. The bivariate analysis did not confirm this expectation. Clearly, there had to be other contextual factors that help explain these differences.

Similarly, Americans living at population densities of over 5,000 people per km^2 traveled about as many kilometers per day as Germans at population densities of less than 2,000 people per km^2. This was contrary to expectations, as theory would suggest that similar people in similar spatial settings should display similar travel behavior, everything else equal. If this held true, Americans living at lower population densities than their German counterparts would be expected to travel less. Shorter travel distances were found with increasing population density in both countries, but theory could not explain differences in travel between the countries. The multivariate regression analysis in the next section sheds more light on difference in travel controlling for other explanatory factors.

8.2 Multivariate Analysis I: Linear Regression with and without Interaction Effects for Daily Travel Distances of less than 200km

The dependent variable for the models presented in this section was total daily travel distance per person. The variable was truncated at 200km and the sample included only individuals who made a trip on the travel day.[108,109] The independent variables captured transportation policies, spatial development patterns, socioeconomic, and demographic variables. Furthermore, proxy variables for macro-economic differences and cultural preferences were included. In contrast to the bivariate analysis above, the regression coefficients controlled for the independent effects of each variable, holding the influence of the other variables constant. An overview of the levels of measurement and ranges of the dependent and independent variables is provided in Table 8.7 below.

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[108] The analyses presented here excluded all daily travel distances of over 200km. As discussed earlier in this chapter, another possibility to overcome the problems of a skewed distribution with outliers is to take the natural log of the variable. This transformation compresses the outliers more than the smaller values and results in a more normally distributed dependent variable. These models are presented in the appendix. The number of cases included in the analysis increased by about 5,000 persons or five percent. These additional cases are all respondents that traveled more than 200km on their travel day. Coefficients for statistically significant independent variables are the same as for the truncated model above, as are the results of the overall F-tests. In contrast to the models presented above, interaction coefficients for transit distance and the age/driver's license variable are not statistically significant in this model. This indicates that the coefficients of these variables on the natural logarithm of daily travel distance are not statistically significantly different in either country. The R^2 is slightly higher for these models than for the truncated models presented here, reaching 17 percent.

[109] Another modeling approach would include non-trip makers with a daily travel distance of 0. This set of models was estimated and is presented in the appendix. The sign and magnitude of most coefficients does not change considerably. As expected, the coefficient for Sunday becomes statistically significant, as people are less likely to make a trip on Sunday compared to weekdays (captured by the 0km for non-trip makers). Additionally, the coefficient for having a valid license is stronger indicating that individuals without a license are less likely to make a trip.

Table 8.7 Dependent and Independent Variables used in Multivariate Regression Analysis

		Level of Measurement	Mean	Min	Max	N
Dependent variable						
	Travel distance	interval ratio	40	0	200	93,347
Independent variables						
Policy	Transit access <400m	nominal/dummy (1= hh within 400m of transit stop)	*n.a.*	0	1	93,109
	Transit access 400-1000m	nominal/dummy (1= hh within 400-1000m of transit stop)	*n.a.*	0	1	93,109
Spatial development patterns	Population density	interval ratio	1778	0.1	9,997	91,836
	Mix of use	interval ratio	0.33	0	1	91,836
Socioeconomic and demographic variables	Household income	interval ratio	53,200	2,500	115,000	89,638
	Car access/availability	interval ratio	0.89	0	4	93,109
	Driver's license	nominal/dummy (1=respondent has driver's license)	*n.a.*	0	1	93,300
	Younger than 16/18	nominal/dummy (1=respondent younger than driving age)	*n.a.*	0	1	92,484
	Employed in single HH	nominal/dummy (1=respondent with job in single HH)	*n.a.*	0	1	93,287
	Unemployed in single HH	nominal/dummy (1=respondent without job in single HH)	*n.a.*	0	1	93,287
	Employed in adult only HH	nominal/dummy (1=respondent with job in 2 pers. HH)	*n.a.*	0	1	93,287
	Unemployed in adult only HH	nominal/dummy (1=respondent without job in 2 pers. HH)	*n.a.*	0	1	93,287
	Employed in HH with small children	nominal/dummy (1=respondent with job in HH with child 0-5)	*n.a.*	0	1	93,287
	Unemployed in HH with small children	nominal/dummy (1=respondent without job in HH with child 0-5)	*n.a.*	0	1	93,287
	Unemployed in HH with school children	nominal/dummy (1=respondent without job in HH with child 6-16/18)	*n.a.*	0	1	93,287
	Retired HH	nominal/dummy (1=respondent retired in retired HH)	*n.a.*	0	1	93,287
	Sex (Male=1)	nominal/dummy (1=male)	*n.a.*	0	1	93,347
Macro-economic differences	Sunday	nominal/dummy (1=Sunday was travel day)	*n.a.*	0	1	93,109
	Germany(1/0)	nominal/dummy (1=Respondent from	*n.a.*	0	1	93,109

(Data: all respondents traveling fewer than 200km per day)

Table 8.8 shows the first set of five nested models. Model 1 included the first two policy variables measuring the distance of the respondent's household to public transportation. Model 2 added two variables capturing spatial development patterns: population density and mix of land use. Model 3 then added socioeconomic and demographic variables. These included car ownership per household member of driving age, household income, license holders, gender, and a set of dummy variables for the household life cycle. The reference category for the life cycle dummy variables was an employed adult in a household with school children. Model 4 added a dummy variable contrasting Sundays with the rest of the week. This served as rough proxy for macro-economic differences, as described above. Finally, Model 5 added a dummy variable, identifying if the respondent resides in Germany or the U.S. This variable captured differences between the two countries not explained by variables included earlier.

All signs were in the expected direction and most coefficients are significant at the one percent level. Sequentially adding groups of variables traced changes in coefficients' magnitude, significance, and sign. This could help detect omitted variable bias and multicoliniarity. For example, the coefficients for distance to a transit stop changed significantly once spatial development patterns were controlled for. Model 5 was the preferred model, as it included all theoretically relevant variables.

Living close to transit, at a higher population density, and in a neighborhood with greater mix of land use reduced daily travel distances. For example, living within 400m of a transit stop compared to households more than 1000m from a transit stop reduced individual daily travel distance by 6.1km. As expected, the magnitude of this effect was less for the intermediate distances: individuals living between 400m and 1000m from a transit traveled only 4.9 fewer kilometers than those living farthest from a transit stop.

Higher incomes and easy access to an automobile led to increased daily travel distance. One additional car per household member increased daily travel distance by 5.1km. Children and teenagers not yet at driving age traveled 11.4km less than employed adults in households with school children. Men traveled 3.9km more per day than women. The Sunday dummy variable was significant at the five percent level in Model 5 and indicated a 1.2km shorter daily travel distance for Sundays. Finally—as expected—being in Germany and not in the U.S., led to shorter travel distances (10.2 fewer kilometers).

The F-tests testing the joint significance of all independent variables were statistically significant. This indicated that the effect of at least one independent variable in each model was not statistically equal to zero. Total variance explained by the independent variables increased for each added variable[110] and reached 14 percent for the last model. These R^2s might seem low, but they were in line with other multivariate analysis performed on NHTS and MiD. The relatively low R^2 was most likely related to the disaggregate nature and the degree of variability of the individual level data of the national travel surveys.

[110] Only marginally, for the dummy variable Sunday, however.

Table 8.8 Dependent Variable: Daily Travel Distance per Person in km

		Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*
	Constant	**51.132**	**57.48**	**37.352**	**37.454**	**42.409**
		(158.39)**	(132.75)**	(45.54)**	(45.68)**	(50.21)**
Policy	Transit access <400m	**-17.654**	**-10.303**	**-8.255**	**-8.255**	**-6.056**
		(44.16)**	(22.40)**	(17.90)**	(17.90)**	(13.08)**
	Transit access 400-1000m	**-16.136**	**-10.524**	**-8.736**	**-8.742**	**-4.896**
		(34.66)**	(21.06)**	(17.50)**	(17.51)**	(9.47)**
Spatial developme nt patterns	Population density		**-3.664**	**-2.78**	**-2.78**	**-1.938**
			(28.07)**	(20.82)**	(20.81)**	(14.47)**
	Mix of use		**-12.574**	**-11.903**	**-11.904**	**-11.877**
			(14.48)**	(13.67)**	(13.67)**	(13.79)**
Socioeconomics and demographics	Household Income			**0.108**	**0.108**	**0.091**
				(14.83)**	(14.83)**	(12.62)**
	Car access/availability			**7.457**	**7.464**	**5.066**
				(17.84)**	(17.84)**	(12.16)**
	Driver's License			**9.881**	**9.881**	**10.118**
				(22.11)**	(22.10)**	(22.81)**
	Younger than 16/18			**-10.913**	**-10.915**	**-11.385**
				(19.12)**	(19.11)**	(20.11)**
	Single HH with Job			**1.881**	**1.881**	**0.063**
				(2.31)*	(2.31)*	(0.08)
	Single HH without Job			**-4.728**	**-4.717**	**-6.44**
				(3.00)**	(2.99)**	(4.06)**
	Couple HH with Job			**1.652**	**1.653**	**0.374**
				(2.97)**	(2.97)**	(0.68)
	Couple HH without Job			**-9.38**	**-9.37**	**-8.362**
				(13.62)**	(13.60)**	(12.27)**
	HH, Small Children with Job			**3.284**	**3.286**	**1.809**
				(4.98)**	(4.99)**	(2.76)**
	HH, Small Children without Job			**-5.682**	**-5.682**	**-6.069**
				(6.63)**	(6.63)**	(7.17)**
	HH, Older Children without Job			**-6.325**	**-6.32**	**-6.123**
				(8.84)**	(8.84)**	(8.61)**
	Retired HH			**-6.378**	**-6.377**	**-6.841**
				(12.82)**	(12.82)**	(13.82)**
	Sex (Male=1)			**3.686**	**3.69**	**3.944**
				(15.64)**	(15.66)**	(16.78)**
Macro-economic differences	Sunday				**-0.864**	**-1.165**
					(1.45)	(1.99)*
	Germany(1/0)					**-10.216**
						(24.30)**
	Observations	**93102**	**91370**	**87897**	**87897**	**87897**
	R-squared	**0.04**	**0.06**	**0.13**	**0.13**	**0.14**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%					

(Data: all respondents traveling fewer than 200km per day)

The final model explained 14 percent of total variability in travel distance. Based on the sequential changes in R^2 for different groups of independent variables the variance explained was distributed as follows: 29 percent of the total variance explained could be attributed to the policy variable (0.04 of 0.14 of variability explained), 14 percent to spatial development patterns (0.02 of 0.14), and 50 percent for socioeconomic and demographic variables (0.07 of 0.14). The Germany/U.S. dummy variable added one percentage point to the R^2 and contributed seven percent of the total variance explained, once the other variables were already in the model. This interpretation of course depended on the order in which the variables were entered and might have had an impact on the magnitude of explanatory power attributed to each group of variables.

Alternatively, five models each including just a single group of independent variables were estimated. These models showed the variance explained uniquely by each group of variables. These models are presented in the appendix. The R^2s for each individual group of independent variables were: four percent for the transportation policies; five percent for spatial development patterns; 10 percent for socioeconomic and demographic variables; 0 percent for the Sunday dummy; and six percent for the Germany/U.S. dummy variable.

The regressions so far have identified the sign, magnitude, and significance of the independent variables in the pooled sample, but have not identified differences in coefficients between Germany and the U.S. Table 8.9 below displays results of nested models with interaction effects for Germany for every independent variable, which show the strength of the variables in each country.

Again all signs were in the expected direction, but not all are significant. The preferred model was Model 4 as it included all statistically significant independent variables. Model 5 additionally included the Sunday dummy, which had the expected sign, but was not statistically significant and did not add to the R^2. The interpretation of specific coefficients below was based on Model 4 if not otherwise indicated.

Table 8.9 Dependent Variable: Daily Travel Distance per Person in km with Interaction Effects

		Model 1	Model 2	Model 3	Model 4	Model 5
Policy	Transit access <400m		**-12.977** (23.72)**	**-6.915** (10.36)**	**-6.603** (9.76)**	**-6.599** (9.75)**
	Transit access <400m G		**7.25** (8.18)**	**2.888** (2.98)**	**3.764** (3.91)**	**3.763** (3.91)**
	Transit access 400-1000m		**-7.822** (9.44)**	**-4.966** (5.85)**	**-5.356** (6.16)**	**-5.346** (6.15)**
	Transit access 400-1000m G		**4.788** (4.36)**	**2.71** (2.43)*	**3.23** (2.89)**	**3.211** (2.87)**
Spatial development patterns	Population density			**-2.894** (13.53)**	**-2.561** (11.52)**	**-2.559** (11.50)**
	Population density G			**1.564** (5.74)**	**1.431** (5.12)**	**1.432** (5.13)**
	Mix of use			**-13.129** (12.21)**	**-12.82** (11.74)**	**-12.816** (11.73)**
	Mix of use G			**-1.629** (0.91)	**-0.289** (0.16)	**-0.315** (0.18)
Socioeconomic and demographic variables	Household income				**0.079** (9.32)**	**0.079** (9.31)**
	Household income G				**0.044** (2.92)**	**0.044** (2.93)**
	Car access/availability				**3.313** (6.41)**	**3.313** (6.40)**
	Car access/availability G				**5.725** (7.02)**	**5.742** (7.03)**
	Driver's License				**11.716** (14.30)**	**11.71** (14.28)**
	Driver's License G				**-3.637** (3.78)**	**-3.629** (3.77)**
	Younger than 16/18				**-12.906** (13.63)**	**-12.913** (13.64)**
	Younger than 16/18 G				**2.929** (2.52)*	**2.93** (2.52)*
	Sex (Male=1)				**2.893** (7.89)**	**2.894** (7.90)**
	Sex (Male=1) G				**2.383** (5.07)**	**2.396** (5.09)**

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Socioeconomics and demographics	Single HH with job				**-2.866** (2.60)**	**-2.866** (2.60)**
	Single HH with job G				**7.096** (4.38)**	**7.085** (4.37)**
	Single HH without job				**-13.333** (5.02)**	**-13.326** (5.01)**
	Single HH without job G				**12.856** (3.93)**	**12.87** (3.93)**
	Couple HH with job				**-0.704** (0.88)	**-0.703** (0.88)
	Couple HH with job G				**2.066** (1.89)	**2.059** (1.89)
	Couple HH without job				**-7.143** (4.36)**	**-7.114** (4.34)**
	Couple HH without job G				**-0.358** (0.20)	**-0.375** (0.21)
	HH, small children with job				**1.673** (1.80)	**1.672** (1.80)
	HH, small children with job G				**-1.139** (0.88)	**-1.138** (0.88)
	HH, small children without job				**-5.859** (4.11)**	**-5.862** (4.11)**
	HH, small children without job G				**-0.047** (0.03)	**-0.042** (0.02)
	HH, older children without job				**-7.733** (6.08)**	**-7.721** (6.07)**
	HH, older children without job G				**3.082** (2.04)*	**3.073** (2.04)*
	Retired HH				**-10.068** (12.32)**	**-10.07** (12.33)**
	Retired HH G				**5.976** (5.90)**	**5.985** (5.91)**
Macro-economic differences	Sunday					**-1.033** (1.16)
	Sunday G					**-0.365** (0.32)
	Germany(1/0)	**-19.295** (58.61)**	**-20.247** (27.69)**	**-18.286** (19.17)**	**-23.836** (14.33)**	**-23.84** (14.34)**
	Constant	**49.154** (189.56)**	**54.24** (151.75)**	**59.516** (113.78)**	**46.807** (38.02)**	**46.951** (38.16)**
	Observations	**93347**	**93102**	**91370**	**87897**	**87897**
	R-squared	**0.06**	**0.07**	**0.08**	**0.14**	**0.14**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%					

(Data: all respondents traveling fewer than 200km per day)

For all models, Germans traveled fewer kilometers per day than Americans. For example, being in Germany and not the U.S. decreased daily travel distance by 23.8km in Model 4.

Living within 400m of a transit stop compared to more than 1000m away reduced daily travel distance by 6.6km in the U.S., but only 2.8km in Germany. The effect for Germany was the *sum* of the U.S. coefficient and the Germany interaction coefficient for transit distance (-6.6+3.8=-2.8). In other words the interaction effect for Germany indicated the *difference* in slope between the two countries. Living between 400m and 1000m from a transit stop compared to greater distances decreased daily travel by slightly fewer kilometers (5.3km in the U.S. and 2.1km in Germany).

Higher population density and greater mix of land use led to shorter daily travel distance in both countries. For population density this effect was significantly weaker for Germany than for the U.S. While an additional 1,000 people per square kilometer led to a 2.6km shorter daily travel distance in the U.S., this was only 1.2km in Germany (2.6-1.4).

An additional car per household member of driving age, led to an increase in daily travel distance of 3.3km in the U.S. This effect was more than twice as strong in Germany: each additional car led to an increase in daily travel distance of 9km.

Higher the household income led to the more kilometers of daily travel in both countries. The effect of income after controlling for car ownership and access was small, however. A $10,000 increase in household income led to a 0.8km increase in daily travel distance in the U.S. For Germany this effect was stronger at 1.1km, but still small given the increase in income. This result suggests that access to a car may influence travel distance more than a household's income level or relative ability to pay for certain types of trips. Men traveled 2.9km more than women in the U.S. and 5.3km more in Germany. In the U.S. individuals with a driver's license traveled 11.7km more than individuals without a license. This effect was slightly smaller in Germany where the difference is 8km.

The reference category for the household life cycle variables was an employed adult in a household with school children. First, in both countries and every household life cycle category, unemployed adults traveled less than employed adults in households with school children. Second, in Germany employed individuals in households without children traveled more kilometers than the reference category. Third, in the U.S. households with children traveled more than households without children. Fourth, in both countries employed adults in households with small children traveled more than the reference category. Fifth, retirees traveled significantly fewer kilometers in both countries (-10.1km in the U.S., but just -4km in Germany). Sixth, children traveled 12.9 fewer kilometers in the U.S. compared to 10km in Germany.

Finally, as displayed in Model 4 travel distances on Sunday were shorter in both countries than during the week. As hypothesized the effect was slightly stronger in Germany. The coefficients are not statistically significant at five percent, however.

Groups of independent variables were added one after the other in the models. The F-statistics for all models were significant, indicating that the effect of at least one of the coefficients was statistically not equal to zero and the independent variables had joint statistical significance in explaining the dependent variable. As each set of variables was added to the model, the change in the R^2 explained the relative impact of that set on distance traveled. Transportation policy variables together with the country dummy explained six percent of the variability in the pooled sample. Spatial development patterns added another one percentage point to the R^2. Socioeconomic and demographic variables added another six percentage points to the R^2. The Sunday dummy only increased the R^2 marginally, so the overall R^2 stayed at 14 percent. Decomposing the total variability into the different components yielded: 50 percent explained by the policy and the dummy variable (0.07 out of a total of 0.14), seven percent for spatial development variables (0.01 of 0.14), and 43 percent for socioeconomic and demographic variables (0.06 of 0.14).

As in the previous set of models, the interpretation of the share of explained variance in this sequential approach depended on the order in which the variables were entered.[111] Models of each set of independent variables were estimated to identify variance explained by each group of variables, and are presented in the appendix. To summarize these models, the R^2s for each set of independent variables were: 0.07 for transportation policies; 0.06 for spatial development patterns; 0.12 for socioeconomic and demographic variables; 0.06 for the Sunday dummy. All groups of variables already included the Germany/U.S. dummy variable.

The standard tests for multicoliniarity (Variance Inflation Factor, Tolerance and Condition Index) did not indicate any serious problems with collinearity among the

[111] Furthermore, the analysis of the interaction effects necessitates the inclusion of the Germany/U.S. dummy variable. The interpretation of changes in the R^2 tries to single out the variance explained by different groups of variables. Unfortunately, the effect of the dummy variable is included in all models. Therefore, the interpretation of R^2 is misleading, as it reflects the percentage of variability explained by the dummy variable *and* the policy variables. The share of explanatory power attributed to the policy variable might be overestimated. This problem did not exist with the regressions without interaction effects presented in the beginning of this chapter. There, the Germany/U.S. dummy was entered in the fifth model and accounted for eight percent of the total variance explained.

explanatory variables.[112] However, given the nature of the household based travel survey data, spatial autocorrelation may have caused inefficient estimators. Multiple regression models assume that errors are uncorrelated. Respondents in the same household faced the same characteristics on variables such as household income or car access; respondents within the same neighborhood, city, or state face similar transportation policies and supply conditions. Therefore these observations and resulting errors were not independent. The statistical package STATA allowed the estimation of coefficients and errors that were robust to spatial autocorrelation. Two such models were estimated and it was found that results did not change significantly. The adjusted standard errors and coefficients accounted for clustering of respondents by household, neighborhood and city, as well as by state.

8.2.1 Extension: Two-Stage Model Controlling for Selection Bias

The regression analyses so far included only individuals who made a trip on the travel day. As discussed above, these estimates could be biased due to selection bias. School children, for example, must make a trip on a travel day, while retired senior citizens have no similar commitment to daily mobility. Likewise, the variable "*Sunday*", which was not significant above, could play a role in the decision to make a trip or not, rather than explaining trip distance.

If such a selection bias exists, modeling only the second equation for trip distance would lead to inconsistent coefficients. Furthermore, a one-stage model on trip distance omits an important part of the travel decision making process. In a first stage individuals decide if they make a trip or not. Then, only if a trip is made, they decide how far to

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[112]For the model with interaction variables, the Germany U.S. dummy variable is the only variable with an elevated VIF (above 10) and small Tolerance (below 0.1).

travel. Therefore a two-stage model was more precise in capturing real world trip decision making than a one-stage model.

Heckman Selection Models (HSM) allow modeling such a two-stage process. HSM in the first stage uses a probit regression to determine if individuals made a trip on a travel day or not. In a second stage HSM model the trip distances for those individuals who were traveling on the travel day.

Equation (12): (Model 6)

STAGE 1: Trip Making (1=yes/0=no) = f (SE, SE(G), M, M(G), CP)

STAGE 2 (only if Stage1=1): Distance = f (TP, TP(G), SD, SD(G), SE, SE(G), M, M(G), CP)

(With SE, SE(G), M, M(G), CP, TP, TP(G), SD, SD(G) defined as in Chapter 6)

The model specification allowed correlation between variables and errors of stage one and stage two (Cao et al., 2006; Kennedy, 2003; Xinyu, Mokhtarian, & Handy, 2006). The two equations were estimated simultaneously taking the correlation of variables and errors into account. In practice it has been common to use at least one variable that was the same in both stages of the modeling and at least one variable that was different in both stages (Cao et al., 2006; Kennedy, 2003; Xinyu et al., 2006). This was appropriate for this analysis as similar variables helped explain the choice to make a trip and travel distance.

HSMs estimated the linear model on the second equation using a variable accounting for the non-selection probability from stage one (The so called Inverse Mills-

Ratio (IMR), which was—in the case of a probit regression in stage one—calculated as (PDF(Beta' X)/CDF(Beta' X)) of the assumed normal distribution[113]).

Results of HSMs were sensitive to model specification, in particular to the correlation of variables and errors between the probit and the linear regression. Therefore a nested modeling approach—where each group of variables was entered into the model separately—was not feasible. Consequently, only one final HSM model was estimated.

Variables to be included in the first stage of the model were mainly socioeconomic variables and the *Sunday* variable. It was expected that individuals were less likely to make a trip on Sundays, compared to weekdays. Furthermore it was expected that the elderly and individuals of driving age and without driver's license were less likely to make trips. Based on empirical findings from Germany, children were expected to display a higher likelihood of making a trip than adults. Additionally, German data suggested that women were less likely to make trips than men. The variables included in the linear model (stage two) were the same as in the models estimated above. Expected direction of the coefficients in the stage two equation was also the same.

A look at the percentage distribution of trip makers and non-trip makers in the sample showed that the variables identified may indeed give rise to sample selection bias (see Table 8.10 below). Individuals who were retired; individuals without a job; individuals without a license, as well as individuals residing in households with fewer cars per household member were less likely to make a trip on a travel day than the average.

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[113] PDF=probability density function and CDF=cumulative distribution function of a normal distribution, which was assumed for probit models.

Table 8.10 Percent of Respondents not Making a Trip on Travel Day

	Germany	USA
Average	13.5	12.7
Men	12.3	10.9
Women	14.8	14.4
License	12.9	10.1
No License	15.0	19.0
<0.5 cars per hh member	19.5	29.9
0.5<1 cars per hh member	14.0	18.5
1<1.5 cars per hh member	10.7	11.1
1.5+ cars per hh member	10.6	9.2
Kid / teenager	13.1	14.6
with job in single HH	11.4	6.5
w/o job in single HH	15.8	30.8
with job in couple HH	11.1	7.9
w/o job in couple HH	18.0	23.3
with job in HH with child <6	8.2	8.2
w/o job in HH with child <6	14.4	13.5
with job in HH with child 6-16	9.7	6.3
w/o job in HH with child 6-16	15.6	19.6
retired in retired HH	18.3	20.8
Sunday	25.1	17.6
Weekdays	11.7	11.9

The results of the HSM model are displayed in Table 8.11. It contains four columns: column one displays results of the probit equation identifying the choice of traveling on a given day; column two displays the linear equation for stage 2—for those respondents who chose to travel; column three adjusts the coefficients for stage 2; and column four shows the marginal change in probability for trip making setting all variables at their averages.

The coefficients for the probit model and for the variables included only in the distance model can be directly read interpreted in the table. An interpretation in terms of probability of making a trip was more straightforward and given in column four. Having easy access to a car and being male increased the probability of making a trip in both countries. The effect for Germany was slightly lower than for the U.S. for both variables. The model showed that a small change in the number of cars per household member led to a 1.1 percent increase in the probability of making a trip on the travel day in the U.S., compared to a two percent change in probability in Germany[114] (see column four). Being retired decreased the probability of trip making by 12 percent in the U.S. and 6.6 percent in Germany. Again, the effects in Germany were less pronounced. Being a child or teenager increased the probability of making a trip in the U.S. by 4.4 percent and 7.2 percent in Germany. This finding was in line with other German studies suggesting that kids and teenagers had a higher propensity to make a trip. Faced with similar empirical findings for Germany, German researchers concluded that teenagers are more likely to make trips regularly as they have to go to school every day (DIW, 1993, 2004).

The variable Sunday had a negative effect on the likelihood of making a trip. As expected the probability of making a trip on Sunday was lower in Germany (-11.7 percent) than the U.S. (-6 percent). This was most likely related to less retail activity on Sundays in Germany compared to the U.S. Being in Germany reduced the probability of making a trip by 1.2 percent compared to being in the U.S.

The coefficients and their direction in the travel distance equation were similar to the linear models presented earlier in this chapter. Living close to transit, at a higher population density, or in mixed use neighborhoods reduced travel distance in both countries. Higher household income led to greater average daily travel distances.

[114] This interpretation is based on a partial change approach for continuous and on a discrete change approach for dummy variables.

In order to interpret the coefficients shaded in grey, it was necessary to take the coefficients of the probit model and the selection probability into account (Dougherty, 2004; STATA Listserve, 2003). The transformed coefficients were given here as their magnitude and sign were similar to the coefficients presented here.

Model fit for HSM could be assessed using three statistics. The first was an overall Likelihood Ratio test (LR), which tested the null hypothesis that the model was not a good fit. The LR test in this case had a chi-square distribution and the null hypothesis could therefore be rejected, indicating that the model was a good fit. The second test involved the significance of the estimated selection parameter *rho*. If *rho* was statistically significant, then there was a selection bias and the HSM was an appropriate model. Again the null hypothesis of no selection bias could be rejected. Based on these two tests, the HSM was a good fit. The third test was another LR test with the null hypothesis that there was no selection bias. This test was similar to the t-test for *rho,* but was chi square distributed. Chi-square for this test was 75.81 with one degree of freedom; therefore the null hypothesis could be rejected again.

These three statistical tests confirmed that there was a selection bias and that HSM was appropriate. The small changes in coefficients for the HSM compared to the OLS only models, however, indicate that the existing selection bias did not affect the estimation significantly. As this was the case OLS models were preferred, as they were straightforward and allowed for a nested modeling structure that controlled for changes in R^2.

Table 8.11 Heckman Selection Model for Mobility Choice and Daily Trip Distance

		STAGE 1 Person was mobile (1/0)	STAGE 2 Travel distance	*Marginal Change in Probabilty to Make a Trip at the Mean*
Policy	Transit access <400m		**-6.653** (13.90)**	
	Transit access <400m G		**3.811** (4.92)**	
	Transit access 400-1000m		**-5.288** (8.77)**	
	Transit access 400-1000m G		**3.222** (3.70)**	
Spatial development patterns	Population density		**-2.63** (17.23)**	
	Population density G		**1.449** (6.48)**	
	Mix of use		**-12.802** (16.73)**	
	Mix of use G		**-0.314** (0.21)	
Socioeconomic and demographic variables	Household income	**0.003** (12.81)**	**0.081** (14.04)**	**0.06%**
	Household income G	**0.002** (2.96)**	**0.05** (3.80)**	**0.09%**
	Car access/availability	**0.069** (4.62)**	**4.207** (11.70)**	**1.10%**
	Car access/availability G	**0.032** (1.16)	**6.372** (9.40)**	**2%**
	License	**0.756** (28.56)**		**16.00%**
	License G	**-0.429** (12.34)**		**7.60%**
	Younger than 16/18	**0.313** (8.98)**	**-22.701** (40.62)**	**4.40%**
	Younger than 16/18 G	**0.136** (2.88)**	**4.956** (6.14)**	**7.20%**
	Sex (Male=1)	**0.074** (5.02)**		**1.50%**
	Sex (Male=1) G	**-0.014** (0.68)		**0.90%**

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Socioeconomic and demographic variables	Single HH with job	**0.098** (2.08)*	**-2.995** (3.14)**	**1.90%**
	Single HH with job G	**-0.009** (0.13)	**7.388** (4.77)**	**1.50%**
	Single HH without job	**-0.562** (7.39)**	**-13.632** (5.58)**	**-15.20%**
	Single HH without job G	**0.578** (5.31)**	**13.66** (4.20)**	**-7.40%**
	Couple HH with job	**-0.126** (4.29)**	**-0.353** (0.57)	**-2.40%**
	Couple HH with job G	**0.157** (3.78)**	**1.935** (2.04)*	**0.10%**
	Couple HH without job	**-0.616** (13.75)**	**-7.375** (5.67)**	**-16.00%**
	Couple HH without job G	**0.412** (7.76)**	**-0.404** -0.27	**-9.90%**
	HH, small children with job	**-0.109** (3.26)**	**2.092** (2.93)**	**-2.20%**
	HH, small children with job G	**0.316** (6.14)**	**-1.318** (1.16)	**2.70%**
	HH, small children without job	**-0.49** (11.00)**	**-6.356** (5.25)**	**-12.40%**
	HH, small children without job G	**0.45** (7.29)**	**-1.465** (0.89)	**-6.00%**
	HH, older children without job	**-0.485** (11.93)**	**-8.177** (7.48)**	**-12.10%**
	HH, older children without job G	**0.354** (6.68)**	**2.461** (1.74)	**-6.40%**
	Retired HH	**-0.525** (19.86)**	**-9.387** (14.93)**	**-12.30%**
	Retired HH G	**0.351** (10.26)**	**5.066** (6.00)**	**-6.60%**
Macro-economic differences	Sunday	**-0.291** (15.28)**		**-6.00%**
	Sunday G	**-0.257** (9.75)**		**-11.70%**
	Germany(1/0)	**-0.107** (2.27)*	**-26.233** (20.52)**	**-1.20%**
	Constant	**0.512** (14.59)**	**59.314** (76.95)**	
	Observations	**101867**	**101867**	
	Likelihood Ratio	-482373		
	LR Test (Chi Square(31)=12853)	**Prob > Chi Square=0.000**		
	Rho (Athrho)	**-0.15** (-10.8)**		

Absolute value of z statistics in parentheses

* significant at 5%; ** significant at 1%, coefficients of variables in both models shaded in grey

8.3 Simulations

So far the multivariate analyses have quantified the relative impact of explanatory variables on travel within each country and the relative impact between the two countries. Using the estimated models' coefficients in simulations, helped capture more of the variability between the countries. The following simulations showed how differences in daily travel between the countries changed if certain key variables were manipulated. The simulations controlled for other variables, by setting them at their mean values. Model 5 of the second set of multivariate models with interaction effects was used for the simulation.

Setting all variables at their mean values yielded an estimated average daily travel distance of 26.8km for Germany and 46.2km for the U.S. (see Table 8.12 below). These values were close to the actual mean of daily travel distance (truncated at 200km). The difference in daily travel between an average person in the U.S. and Germany was 42 percent.

Plugging the U.S. mean values into the German equation and the German mean values into the U.S. equation yielded insight into differences in the travel systems. If Germany had the same average population density, mix of use, and transit access as the U.S. and vice versa, then the difference in kilometers of daily travel would shrink to 25 percent. If each country had the other's household income, car ownership, and share of household life cycle stages then predicted differences in total daily travel distance would fall to 21 percent. The difference in daily kilometers of travel between average individuals in both countries would be eliminated if America and Germany would swap all their mean values for every variable included in this model.

This initial simulation switched all variables in succession by variable groups and then all at once. The complete exchange was unrealistic, as Germany and the U.S. will not change in all aspects to become similar. Furthermore, the simulations of full variable sets presented above were unrealistic as well, since they imply significant changes such as, a doubling of average settlement densities in the U.S. The final set of simulations investigated changes in daily travel distance based on variations of single variables. All other variables were set at their mean values. Results are summarized in Table 8.12 below. Single variables were manipulated and set at the same level in both countries. This showed how differences in travel between the two countries varied as these independent variables changed from low to high values.

In the first simulation, distance to a transit stop was set at farther than 1km. The simulation showed that Germans and Americans traveled 29.6km and 48.9km per day respectively. The difference in daily kilometers of travel between the countries was 39 percent, slightly less than for the base case with all variables set at their means. Individuals living within 400 meters of a transit stop traveled 26.2km in Germany and 42.3km in the U.S. The difference in daily travel distance was only 38 percent between the countries—five percentage points less than in the base case. Individuals living close to a transit stop in the U.S. and Germany displayed more similar travel behavior than the average German and American.

Other modeling results are displayed in Table 8.12. Individuals at higher population densities, households with more cars per household member, higher income households, and females in Germany and the U.S. displayed more similar travel behavior than the average German and American. According to this simulation individuals living at population densities of 5,000 people per km^2 in Germany and the U.S. only displayed a 34 percent difference in daily travel distance compared to 42 percent for an average individual with all variables set at the mean. Interestingly, the percentage difference in daily kilometers increased with greater mix of land use. This indicated that mix of land use had a stronger effect on travel distance in Germany than in the U.S. This was potentially related to generally more spread out settlement patterns outside of the mixed-use neighborhood in the U.S.

Households with higher incomes traveled more kilometers in both countries. The percentage difference in travel was smaller for households with an annual income of $75,000 than for the average household. This confirmed travel behavior theory, which suggests that higher income groups travel more.

According to this simulation German children and teenagers traveled 44 percent fewer kilometers per day compared to their American counterparts. One explanation might be greater distances between destinations for children and teenagers in the U.S., due to more sprawling land use patterns. In Germany many children could still walk to school or to activities such as visiting friends, music lessons or sport activities.

Retired Germans traveled 47 percent fewer kilometers per day than similar Americans. The reason for this might lie in different developments of mobility in both countries. The elderly in the U.S. today experienced mass-automobile ownership much earlier than the Germans of similar age. Consequently, this cohort of Americans uses the automobile more at an older age compared to Germans. As expected the percentage difference in daily kilometers of travel was larger between women than men; potentially indicating a more traditional homemaker role for many German women. Other simulation results can be read from the table below.

Table 8.12 Simulation Results: Impact of Independent Variables on Difference in Daily Travel Distance

Base Case (all variables at their mean)					
	Germany		**USA**		**Difference Germany vs. USA**
All variables at averages	26.8		46.2		42%
Swapped averages (US model with German averages an vice versa)					
	Germany		**USA**		**Difference Germany vs. USA**
Swapped transport policy averages	27.9		43.5		36%
Swapped spatial development pattern averages	28.7		42.2		32%
Swapped socioeconomic and demographic variables	33.4		42.2		21%
Swapped transport policies and spatial develoment patterns	29.8		39.5		25%
Swapped averages	36.4		35.4		-3%
Effect of Individual Transport Policy Variables					
	Germany		**USA**		**Difference Germany vs. USA**
Transit farther than 1000m, other as base case	29.6		48.9		39%
Transit within 400-1000m, other as base case	26.9		43.6		38%
Transit within 400m, other as base case	26.2		42.3		38%
Effect of Individual Spatial Development Pattern Variables					
	Germany		**USA**		**Difference Germany vs. USA**
Density=1000, other as base case	28.5		46.4		39%
Density=2500, other as base case	26.9		42.6		37%
Density=5000, other as base case	24		36.2		34%
Mix of use=0.25, other as base case	28		47.1		41%
Mix of use=0.5, other as base case	24.7		43.9		44%
Mix of use=0.75, other as base case	21.5		40.7		47%
Effects of Individual Socioeconomic and Demographic Variables					
	Germany		**USA**		**Difference Germany vs. USA**
Cars per HH member= 0.5, other as base	25.1		44.2		43%
Cars per HH member= 1, other as base	29.7		45.9		35%
Cars per HH member= 1.5, other as base	34.2		47.5		28%
HH income= 10,000, other as base case	22.1		42.4		48%
HH income= 35,000, other as base case	25.2		44.4		43%
HH income= 75,000, other as base case	30.1		47.5		37%
Child/teenager=1, other as base case	23.6		42.5		44%
Female=1, other as base case	24.2		44.8		46%
Female=0, other as base case	29.5		47.7		38%
Retired=1, other as base case	29.5		45.3		35%
License=1, other as base case	29.2		49.4		41%
License=0, other as base case	21.2		37.7		44%

8.4 Conclusion

The bivariate and multivariate analyses, as well as the simulations yielded consistent results concerning most stated hypotheses. Living closer to a transit stop, at higher population densities, and in mixed land-use areas were related to shorter daily travel distances in both countries. Higher incomes, easier access to an automobile, and being male resulted in longer travel distances in both countries. Not having a driver's license, being under driving age or retired, being female, and traveling on a Sunday compared to a weekday resulted in overall shorter daily travel distances in both countries.

The empirical results also supported most of the hypotheses about differences in the magnitude of the coefficients of independent variables between the U.S. and Germany. Distance to a transit stop, population density, holding a valid driver's license, and age had a weaker influence in Germany compared to the U.S. Income, sex, and access to an automobile, on the other hand, had a stronger influence in Germany.

Overall the variability explained by the independent variables reached 14 percent for the final models. Spatial development patterns accounted for about 20 percent and the policy proxy for about 15 percent of the total variability explained. Socioeconomic and demographic variables explained the largest single share of variability (about 50 percent), while the US-Germany dummy variable accounted for roughly 15 percent.

Heckman selection models (HSM) helped control for selection bias in the sample by representing the trip decision making process more realistically. While all statistical tests identified the presence of selection bias, its impact on the magnitude and sign of coefficients in the OLS travel distance equation was minimal. The HSM models identified access to a car, age, holding a valid driver's license, and Sunday as statistically significant variables to explain the choice of making a trip on the travel day or not.

Additionally, the bivariate analysis showed that similar people or similar spatial development patterns in both countries did not lead to identical travel behavior. For example, the highest income quartile in Germany traveled less than the lowest income quartile in the U.S. Germans living at lower densities traveled less than Americans living at higher densities.

The simulations confirmed this. Similar individuals in Germany and the U.S. had more similar travel behavior than the average American and German, but differences remained. For example, Germans in households with more cars than drivers had more similar travel behavior to Americans in households with many cars. But Germans, who owned many cars, still traveled 27 percent fewer kilometers than Americans with similar car access levels. The next chapter will investigate differences and similarities in daily kilometers of car travel in both countries.

9 Modeling Daily Travel Distance by Car

Chapter 8 investigated differences and similarities in total daily travel distance in Germany and the U.S. It was shown that one of the main drivers of longer daily travel distances in the U.S. compared to Germany was the higher share of trips made by car. Reliance on the automobile as the primary mode of transportation causes economic, environmental, and social problems for communities and the nation. Negative externalities of automobile travel include: environmental pollution; loss of open space; obesity due to sedentary life styles; deaths and injuries in traffic accidents; loss of productive working time due to traffic congestion; dependency on imported oil; as well as exclusion and lack of accessibility for low income residents (Bullard, 2004; CDC, 2005; Downs, 2004; NHTSA, 2004; Texas Transportation Institute, 2005). The costs of these negative externalities are likely to increase in coming decades assuming historical trends in car travel continue.

This chapter investigates explanatory factors for differences and similarities in daily kilometers of car use. Findings from the models will help shed light on specific national contexts and the influence of policies in shaping car travel. This analysis complements the analysis in Chapter 8 and includes two additional variables that capture major differences in transportation policies in the two countries: *cost per kilometer of car travel* and *relative speed* of the car compared to other modes.

As explained in Chapter 6, the *cost per kilometer* variable was added to the NHTS and MiD surveys. The evolution of policies toward taxation of gasoline and the fuel efficiency of the vehicle fleet in Germany and the U.S. were discussed in Chapter 4.

These very different approaches resulted in gasoline prices that were twice as high in Germany than in the U.S. in 2001/2002, when the NHTS and MiD surveys were conducted.

The relative speed variable compared the speed of the automobile to that of other modes (transit, walk, and bike). As explained in Chapter 6, this variable was calculated based on relative travel speeds by trip-distance categories for both countries.[115] For all trip distances other modes of transportation had slower average speeds than automobiles. The speed difference between other modes and the car was much more pronounced in the U.S. than in Germany. This made the car more attractive and competitive in the U.S. than in Germany. Slower car speeds in Germany, were potentially a function of lower speed limits in residential neighborhoods and fewer kilometers of road per inhabitant due to government funding priorities and geography. While U.S. government policies focused on the automobile and neglected other modes of transportation for several decades, in Germany other modes of transportation received high levels of funding at all levels of government, even as road transportation was made a top priority.

Other explanatory variables were the same as for the analysis of daily travel distance. For this multivariate analysis, linear OLS regressions were estimated. Daily travel distance by car was regressed on transportation policies, spatial development patterns, socioeconomic and demographic variables, macro-economic differences, and culture.

The units of analysis were individuals who made a car trip on the travel day—excluding individuals who stayed at home or did not make a car trip during the travel

[115] For details see the variable measurement sections further below.

day.[116] It can be argued that some explanatory variables not only influenced car travel distance, but also affected the decision to travel by car or not on a given day. For example, having a driver's license or living in a household with easy access to a car may have increased the likelihood of making a car trip.[117,118] If this were true, just estimating a regression for car travel distance for the respondents who made a car trip could have led to inefficient and biased estimators, due to sample selection bias. Therefore a two-stage Heckman Selection Model (HSM) was estimated modeling the decision to take a car trip in the first stage and the distance traveled in the second stage. This served as a control for sample selection bias, and more accurately represented the decision making process analyzed here, namely: to make a trip by car; and then how far to travel by car. The decision of making a trip by car might also depend on trip distance, as longer trips are more likely made by car. The variable *relative speed* of transportation modes captured the effect of distance partially, since the ratio of car speed compared to transit, bike, and walking is larger for longer trip distances.

[116] Data about operating cost per kilometer did not exist for individuals who did not make a car trip, as no information about the automobile they could have used was available.

[117] An alternative modeling approach would include non-trip makers in the sample with the value of 0 as travel distance. Such a set of models was also estimated and results are provided in the Appendix. All coefficients have the same signs and about the same strength, compared to the models presented further below. As expected the variables on age and license ownership show slightly stronger coefficients in both countries. Additionally, the variable Weekend (indicating if a trip was made on a Saturday or a Sunday vs. a weekday) is statistically significant, which it is not in the models on distance alone.

[118] Car ownership and holding a valid license are also indicators for mobility preferences. Most likely, individuals who wish to travel by car on the travel day own a car or should have obtained a driver's license already.

9.1 Description of Univariate Distributions and Bivariate Relationships

9.1.1 The Dependent Variable

As discussed earlier, this first analysis included only individuals who made a car trip on the travel day. The descriptives for dependent and independent variables presented here were also only for individuals who traveled by car on the travel day. In Germany, daily travel distance by car ranged from 0.1 to 2500km, with an average of 44.3km and a median of 22km. Car travel distance in the U.S. ranged from 0.2km to 2497.6km, the mean is 70.6km and the median was 41.6km. Both distributions were skewed to the right with 95 percent[119] of all daily car travel distances by car in Germany and the U.S. shorter than 200 kilometers (125 miles). As explained in the last chapter, a skewed distribution of the dependent variable will cause problems for a multivariate regression. Similar to the decision in Chapter 8, the truncated variable was chosen for this analysis as well. Only individuals with total daily car travel distances of less than 200km on the travel day were included in the discussion of independent variables. The descriptive statistics for the original and transformed variables were given in Table 9.1 below.

Table 9.1 Descriptive Statistics for Three Transformations of the Dependent Variable Total Kilometers of Daily Car Travel per Person

	Germany						USA					
	Mean	*Median*	*Std*	*Min*	*Max*	*N*	*Mean*	*Median*	*Std*	*Min*	*Max*	*N*
Daily car travel distance	44.3	22.0	74.8	0.02	2500.0	31,588	70.6	41.6	102.9	0.2	2497.6	48,639
Daily car travel distance (<200km)	33.1	21.0	34.5	0.02	200.0	30,487	50.9	38.4	44.0	0.2	200.0	45,607
LN (daily car travel distance)	3.1	3.1	0.7	-3.9	7.8	31,588	3.6	3.7	1.2	-1.7	7.8	48,639

[119] 96.5 percent for Germany and 93.7 percent for the US.

9.1.2 Explanatory Variables

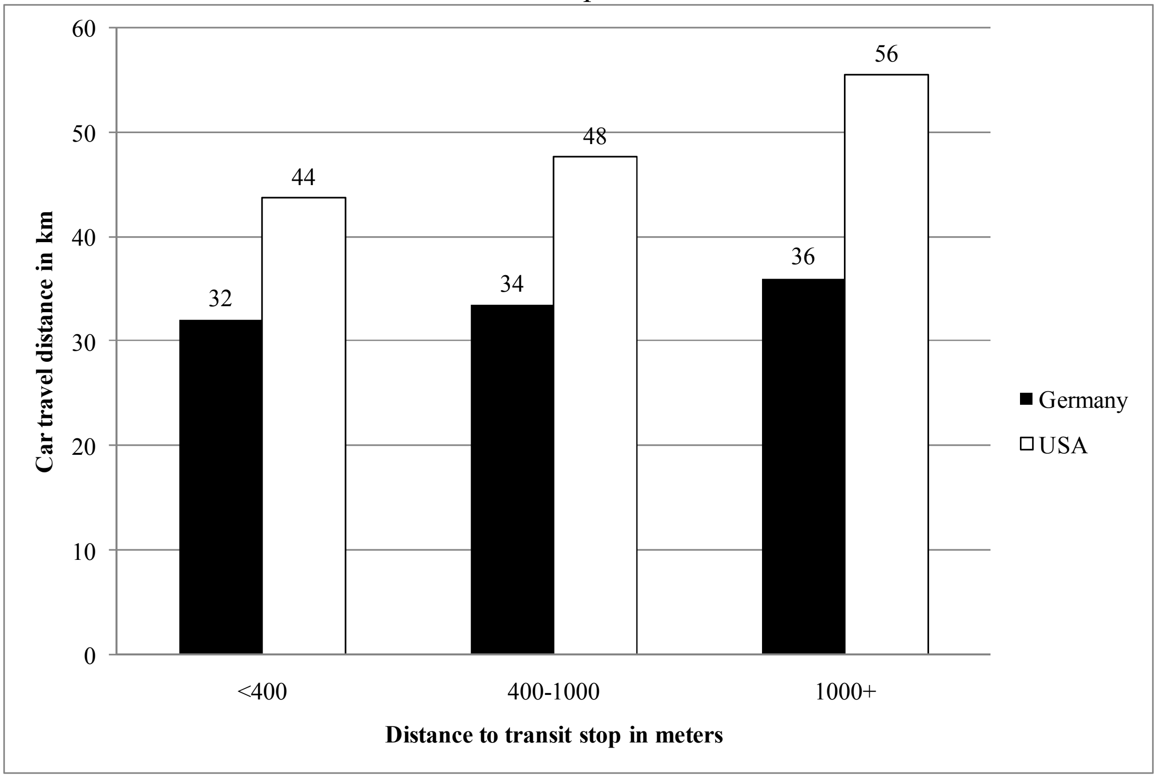
Most univariate descriptives for this sample were similar to the sample for total daily travel distance in Chapter 8 and were presented in an overview table in the multivariate analysis section of this chapter. Some differences did exist, however. Most notably the new variables of *operating costs per kilometer* and *relative speed* were included.

9.1.2.1 Policy Variables

Distance to Public Transportation and Distance Traveled

Exhibit 9.1 shows that easier access to public transportation was related to fewer kilometers of car travel in both countries. In the U.S., individuals who lived within 400m of a transit stop traveled 21 percent fewer kilometers by car per day than individuals residing farther than 1km from a transit stop. Germans living between 400 and 1000m from a transit stop traveled fewer kilometers than similar Americans. The percentage difference of daily kilometers of car travel between households close to transit and farther than 1000m was smaller in Germany than the U.S. Therefore, distance from transit might have had a smaller impact in Germany than the U.S.

Exhibit 9.1 Average Kilometers of Daily Car Travel by Household Distance from Transit Stop



(Data: respondents who drive and travel fewer than 200km by car per day)

Cost of Car Travel per Kilometer

In 2001/2002, the average operating cost per kilometer for a car ranged from 3.6 to 19.1 U.S. cents in Germany and from 1.3 to 12.7 U.S. cents for the U.S. The average operating cost per kilometer was more than double in Germany (9.6 U.S. cents there compared to 4.3 U.S. cents in the U.S.). Both distributions had some extreme outliers to the right. About 465 (1.5 percent) German respondents faced operating costs of more than 14 U.S. cents per kilometer. In the U.S., 497 respondents (about one percent) had operating costs higher than 7.3 cents per kilometer.[120] Descriptive statistics for both the full and truncated variable are shown in Table 9.2.

[120] For both countries two multivariate analyses were conducted once with and once without these outliers—no major changes in coefficients and errors were detected.

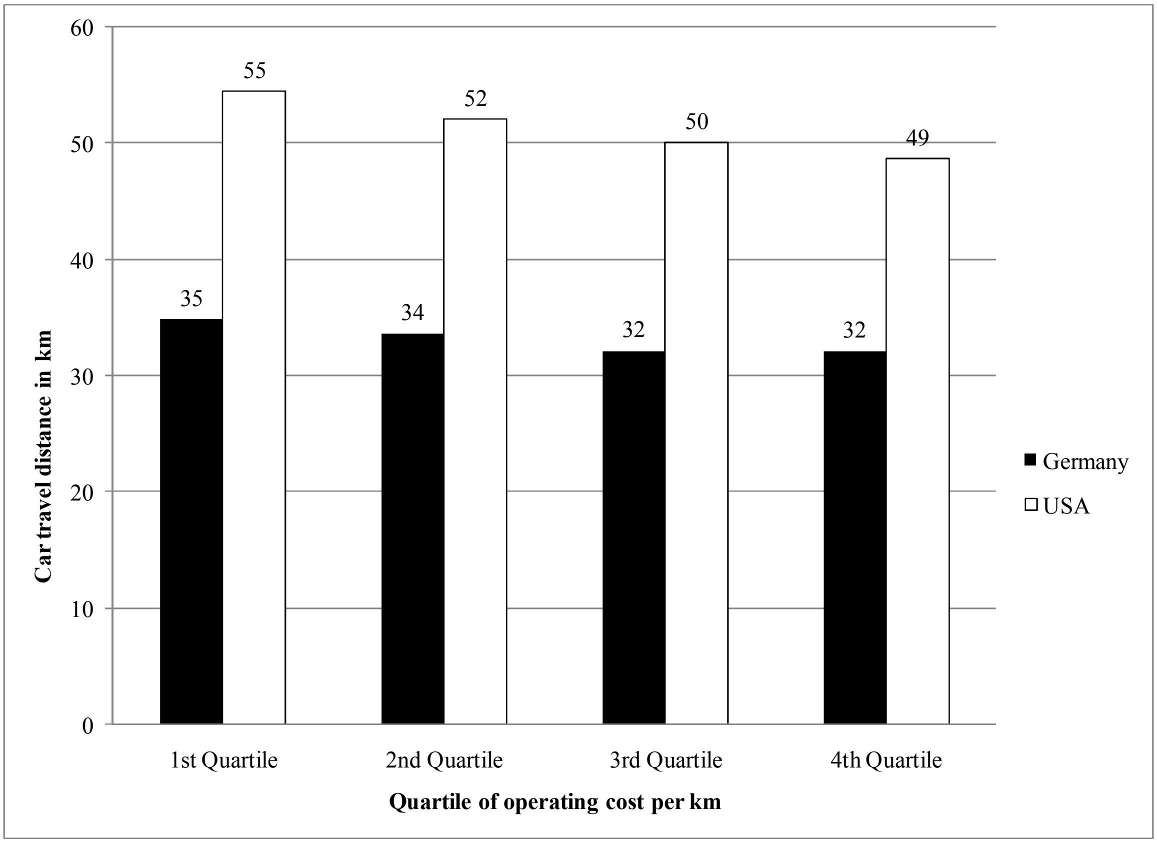
Table 9.2 Descriptive Statistics for Cost per Kilometer of Car Travel in 2001 U.S. Cents

	Germany						U.S.					
	Mean	*Median*	*Std*	*Min*	*Max*	*N*	*Mean*	*Median*	*Std*	*Min*	*Max*	*N*
Cost per km of car travel 1 (2001 U.S. cents)	9.6	9.6	1.7	3.56	19.1	29,909	4.3	4.1	1.0	1.3	12.7	43,383
Cost per km of car travel 2 (2001 U.S. cents)	9.5	9.5	1.6	3.56	14.0	29,444	4.2	4.1	0.9	1.3	12.7	42,886

Cost per Kilometer Driven and Daily Distance by Car

Exhibit 9.2 below presents daily kilometers of car travel in Germany and the U.S. organized by operating cost. For graphical presentation, cost per kilometer of car travel was divided into quartiles. As expected, higher operating costs per kilometer were related to fewer kilometers of car travel per day in both countries. The difference in daily car travel distance between the first and last quartile of operating costs was 11 percent in the U.S., but only 8.5 percent in Germany; indicating that the effect might have been slightly stronger in the U.S. compared to Germany.

Exhibit 9.2 Average Daily Kilometers of Car Travel by Operating Cost per Kilometer (by Quartiles)



(Data: respondents who drive and travel fewer than 200km by car per day)

<u>Relative Speed of the Car Compared to Other Modes</u>

Relative speed of the car compared to other modes served as a proxy for the attractiveness and competitiveness of the transportation modes and the opportunity cost of time. In 2001/2002, a car trip in the U.S. had an average speed of 41km/h, compared to 33km/h in Germany (based on data from NHTS and MiD). Reported average transit speeds (including wait time) were about 18km/h in both countries. Average reported bike trip speeds were 11km/h in Germany and 10km/h in the U.S. Reported speeds of walking trips were 4.5km/h in Germany and 5km/h in the U.S. With average car speeds at least double any other mode in the U.S., the automobile was more competitive relative to Germany.

Travel speeds for most modes of transportation varied by trip distance. Short trips were generally slower than longer trips. Table 9.3 below compares the speed of the automobile relative to other modes of transportation by trip distance for the two countries. The values given are a ratio of the speed of car trips, compared to transit, walking, and cycling respectively.

In both countries and for all trip-distance categories, trips by automobile were generally faster than trips by any other mode of transportation. However, the ratios of average speed of the car compared to other modes were smaller in Germany than in the U.S. This indicates a greater competitiveness and attractiveness of other modes relative to the car in Germany. With increasing trip distance the car got more attractive compared to walking or cycling. For example, for trips less than 0.25 kilometers the car was 1.3 times faster than the bike in Germany and the U.S. For trips between two and three kilometers the average automobile trip was 1.6 times faster than a bike trip in Germany and 2.1 faster than a bike trip in the U.S.

As trip distance increases, the ratio of car speed over transit speed declined in each country. This can likely be explained by the fact that shorter transit trips were made by local busses, whereas longer distance trips were taken by rail or interstate.

Table 9.3 Ratio of Average Cars Travel Speeds to Other Modes of Transportation by Trip-Distance Category

Trip Distance	Ratio Car/Transit Speed		Ratio Car/Bike Speed		Ratio Car/Walk Speed	
	Germany	*USA*	Germany	*USA*	Germany	*USA*
<0.25km	1.5	5.3	1.3	1.3	1.3	1.6
0.25-0.5km	2.2	5.3	1.0	1.4	1.5	2.3
0.5-0.75km	3.2	5.3	1.2	1.4	2.2	2.6
0.75-1km	2.0	5.3	1.5	2.1	2.3	2.5
1-2km	1.8	5.3	1.5	2.5	2.9	4.2
2-3km	2.0	2.4	1.6	2.1	3.8	3.8
3-4km	1.8	3.6	1.6	2.4	4.4	5.8
4-5km	1.9	3.3	1.9	2.2	5.2	6.6
5-6km	1.8	3.0	1.9	2.4	5.4	6.6
6-7km	1.9	3.3	2.1	2.8	5.8	7.8
7-8km	1.9	2.6	2.2	3.0	6.6	8.4
8-9km	1.8	3.1	2.3	3.1	6.8	8.6
9-10km	1.8	2.2	2.6	3.1	7.2	8.6
10-11km	2.1	2.4	2.9	3.4	8.0	9.4
11-12km	1.8	2.4	2.2	3.4	7.6	9.6
12-13km	1.8	2.4	2.7	3.4	8.0	9.6
13-14km	2.1	2.5	2.7	3.6	8.2	10.0
14-15km	1.9	2.5	2.3	3.6	8.4	10.0
15-16km	1.9	2.5	3.4	3.6	8.8	10.0
16-17km	1.7	2.7	2.0	3.9	8.8	10.8
17-18km	1.6	2.7	2.7	3.8	9.2	10.6
18-19km	1.8	2.7	3.5	3.8	9.2	10.6
19-20km	1.6	2.9	3.1	4.1	9.4	11.6
20-30km	1.7	2.2	3.3	4.4	10.0	12.2
30-40km	1.6	2.0	3.7	4.8	11.2	13.4
40-50km	1.7	1.8	4.1	5.1	12.4	14.2
50-100km	1.5	1.4	4.7	5.6	14.0	15.6
100km plus	1.4	1.2	5.8	6.3	17.4	17.6

Table 9.4 below gives descriptive statistics for relative travel speeds of the car compared to other modes of transportation. In Germany, the car was 2.9 times faster than other modes of transportation; while in the U.S. the car was 4.4 times faster than other modes. Relative speeds were only used in the first stage equation of the HSM model, helping explain the choice of making a car trip or not.

Table 9.4 Descriptive Statistics of Relative Speed of the Car Compared to Other Modes, Expressed as Ratio of Car to Other Mode speeds

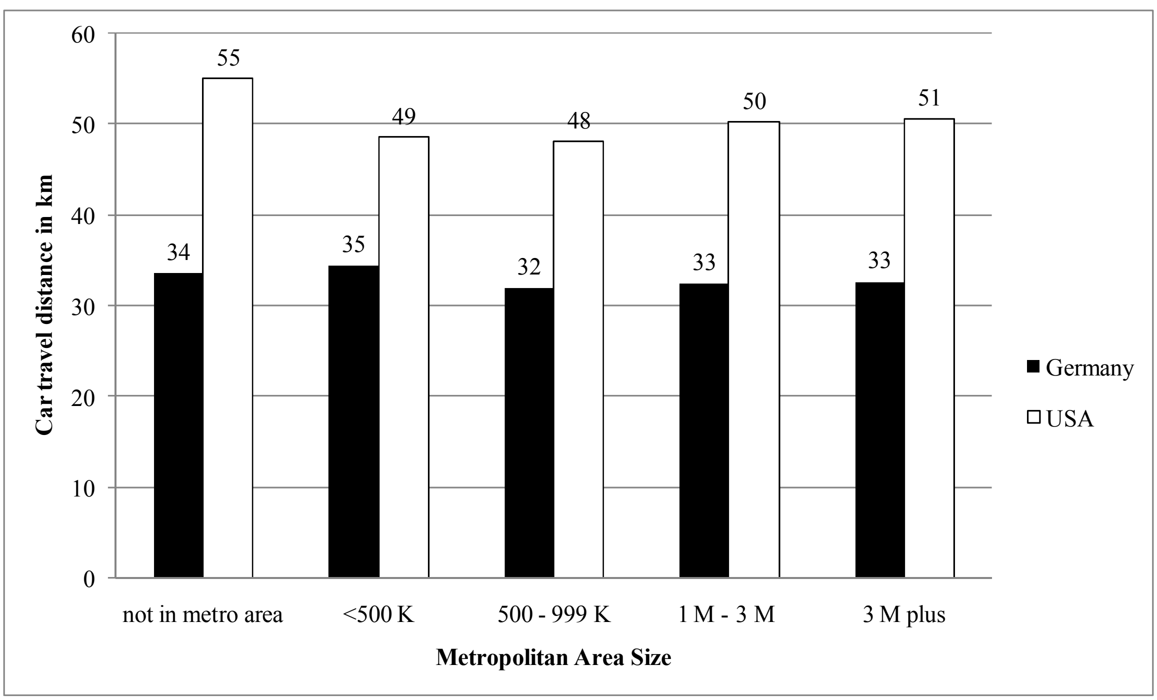
	Germany						U.S.					
	Mean	*Median*	*Std*	*Min*	*Max*	*N*	*Mean*	*Median*	*Std*	*Min*	*Max*	*N*
Relative speed	2.9	2.8	0.6	1.40	4.6	30,487	4.4	4.3	0.7	2.6	6.4	45,607
Relative generalized cost	3.2	3.0	0.6	1.34	6.6	29,673	4.0	4.0	0.7	1.3	7.3	42,552

9.1.2.2 Spatial Development Patterns

Metropolitan Area Size

Similar to Chapter 8, the data for this analysis did not show significant differences in daily car travel distance across metropolitan area size categories (see Exhibit 9.3 below). Furthermore, metropolitan area size was correlated with the other spatial development and policy variables—thus causing multicolliniarity problems in the analysis. Metropolitan area size was therefore eliminated from the distance of car travel analyses.

Exhibit 9.3 Average Daily Kilometers of Car Travel by Metropolitan Area Size Category

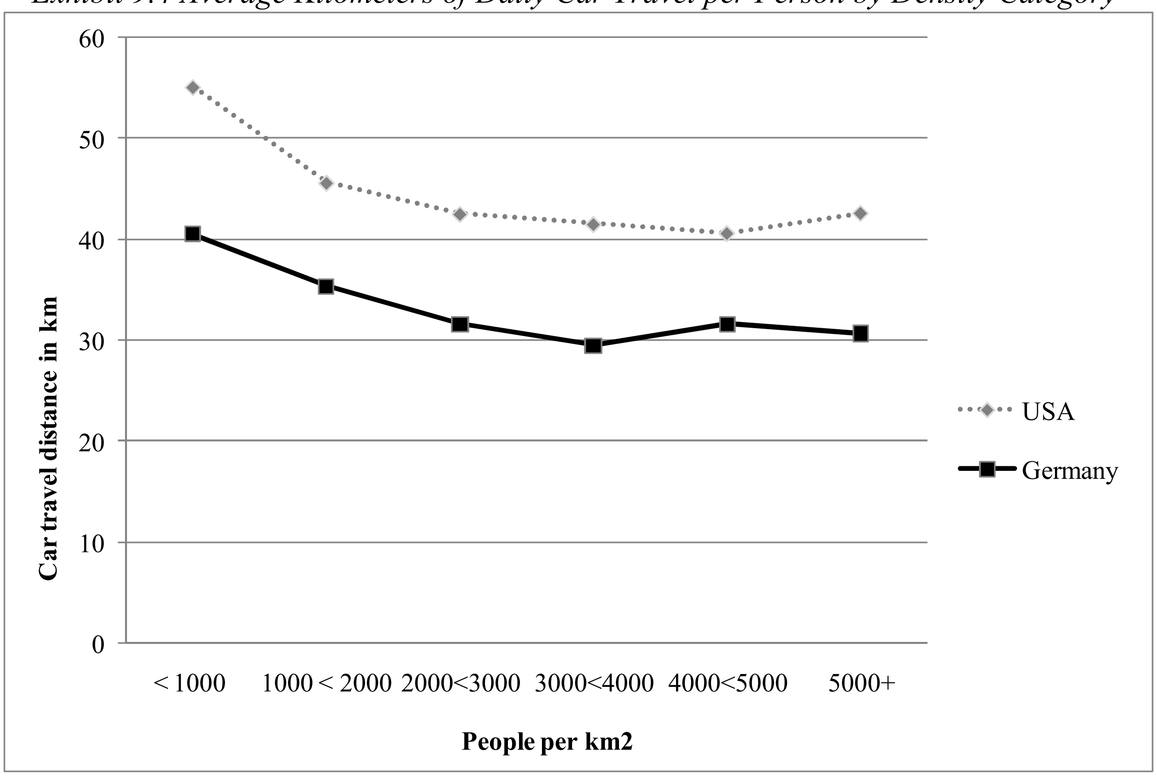


(Data: respondents who drive and travel fewer than 200km by car per day)

Population Density

Exhibit 9.4 below shows, that population density was related to daily kilometers of car travel. The greater the population density was, the fewer kilometers were traveled by car per person per day. Interestingly, Americans in the highest population density category traveled about the same distance by car per day as Germans in the lowest density categories. Density clearly played a role in explaining daily travel distance in both countries, but on different levels. Across all population density categories, Americans traveled about 30 percent more kilometers by car than their German counterparts living at similar population densities.

Exhibit 9.4 Average Kilometers of Daily Car Travel per Person by Density Category

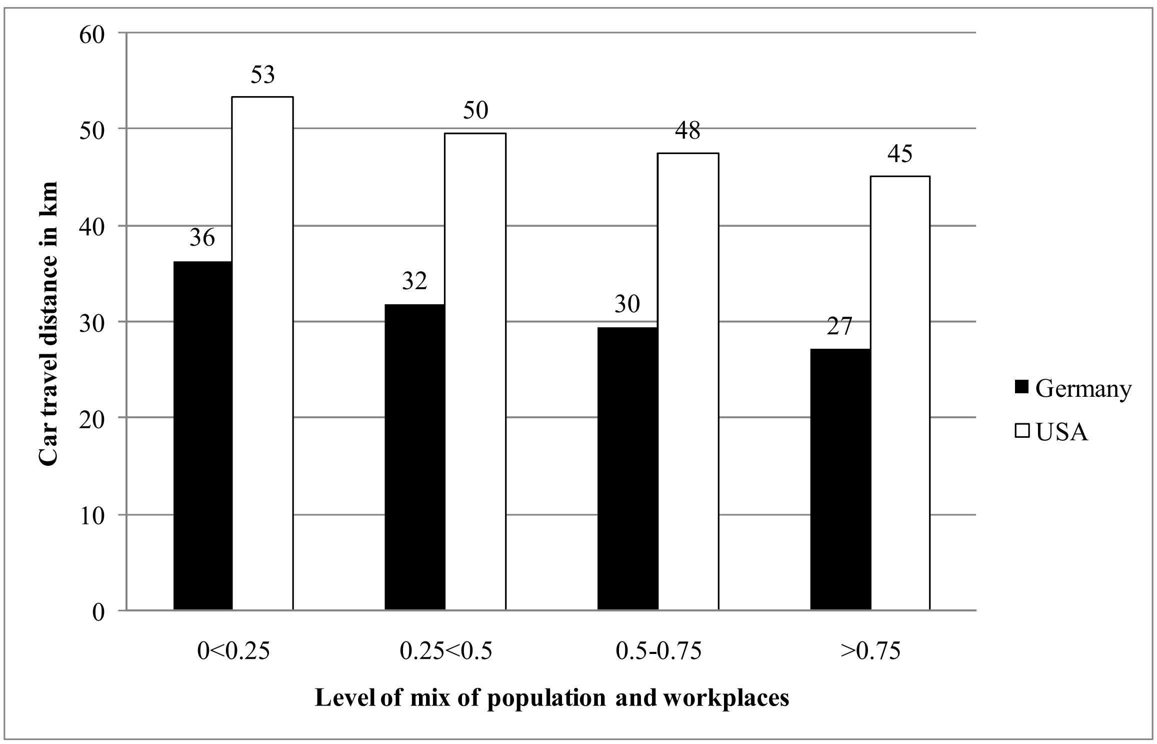


(Data: respondents who drive and travel fewer than 200km by car per day)

Mix of Land Uses

Exhibit 9.5 shows that in both countries greater mix of workplaces and population was related to fewer kilometers of car travel. Similar to the findings for population density, while mixed land use had the same effect on car travel distance, both countries were on different levels. Americans living in the highest mixed-use category traveled more kilometers a day than Germans in the lowest mixed-use category. In every category, however, Americans traveled between 50 and 75 percent more kilometers by car per day than Germans.

Exhibit 9.5 Average Kilometers of Daily Travel by Mix of Land-Use Categories



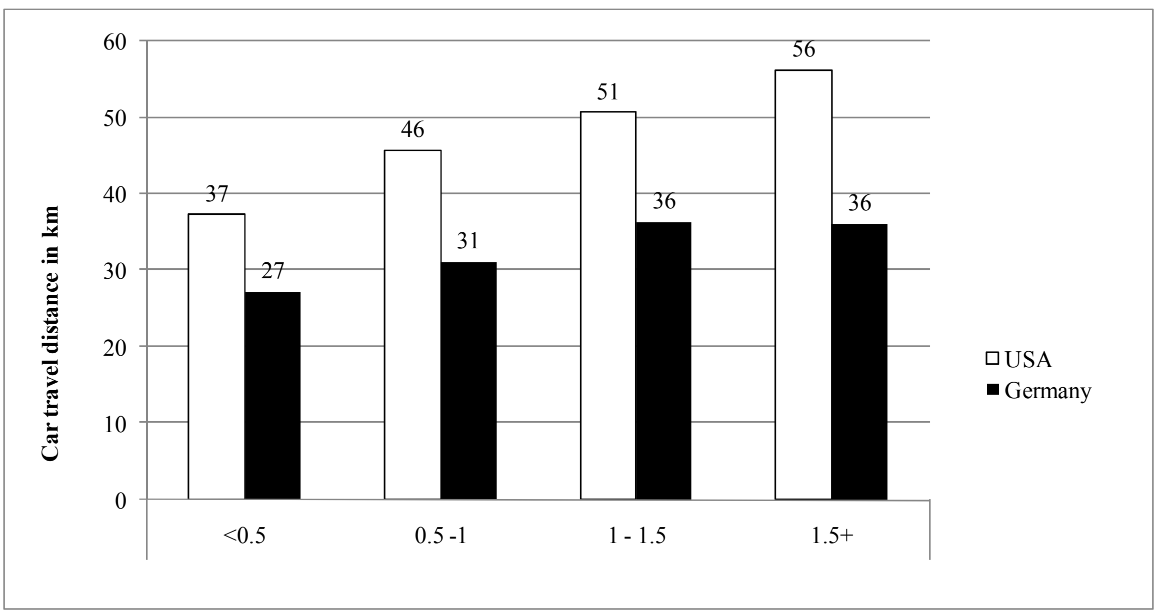
(Data: respondents who drive and travel fewer than 200km by car per day)

9.1.2.3 <u>Socioeconomic and Demographic Variables</u>

Cars per Household and Travel Distance

In both countries, easy access to an automobile was connected to more kilometers of daily car travel, though causation could go in both directions (Schimek, 1997). For example, households with higher mobility needs might own more vehicles, but households who own more vehicles might travel longer distances by car, because they are able to do so. In both countries, households with less than 0.5 cars per driver traveled about 50 percent fewer kilometers a day than households with 1.5 cars per driver (see Exhibit 9.6 below). Americans in households with 0.5 to 1 cars per household member still traveled more kilometers by car per day than Germans in households with more than 1.5 cars per household member.

Exhibit 9.6 Average Kilometers of Daily Car Travel by Number of Cars per Household Member at Driving Age

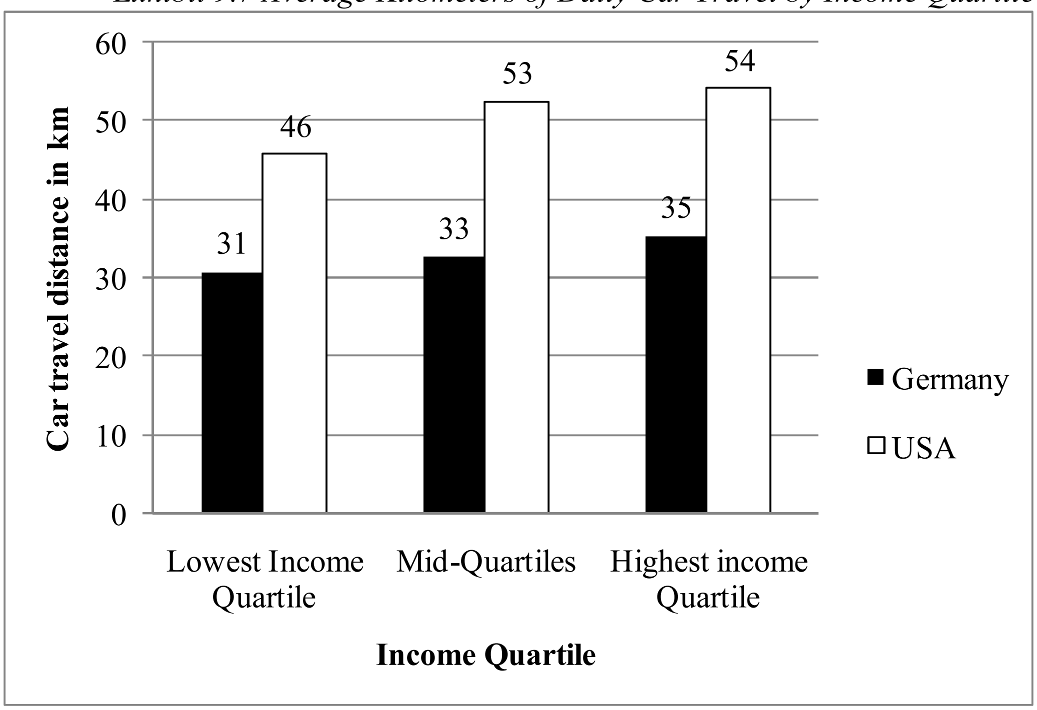


(Data: respondents who drive and travel fewer than 200km by car per day)

Household Income and Travel Distance

For graphical presentation of the bivariate relationship, households were grouped by income quartiles as shown in the graph below. The regression analysis included income as an interval ratio variable. In both countries, higher household incomes were related to longer daily travel distances by car. Similar to the observations for spatial development patterns variables, the lowest income quartile in the U.S. traveled more kilometers by car per day than Germans in the highest income quartile (see Exhibit 9.7 below). Americans in the same income quartile as Germans traveled about 50 percent more kilometers by car per day.

Exhibit 9.7 Average Kilometers of Daily Car Travel by Income Quartile



(Data: respondents who drive and travel fewer than 200km by car per day)

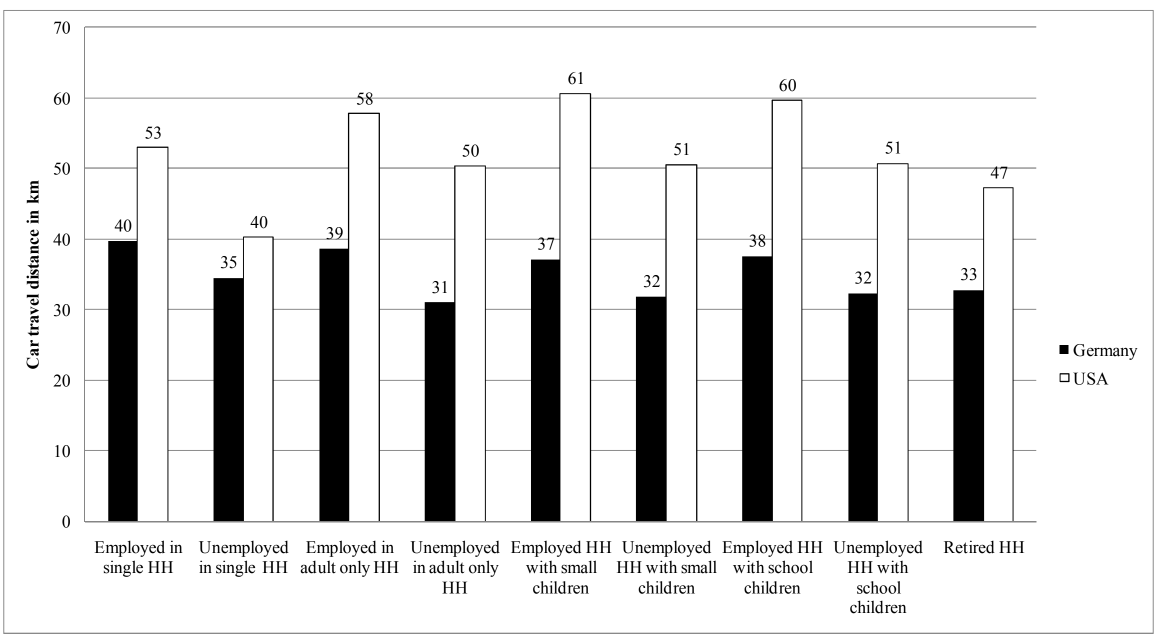
Travel Distance by Driver's License, Gender, and Age

Not surprisingly respondents with a driver's license traveled more kilometers by car in both countries: in the U.S. individuals with a license drove 55.3 kilometers and those without drove 36.7 kilometers. Those compared to 35.7 and 22.9 kilometers in Germany for individuals with and without license respectively. As expected, in both countries women traveled fewer kilometers per day than men (49km compared to 53.1km in the U.S.; and 30.4km compared to 35.8km in Germany). Interestingly, daily average travel distance for adult Germans (35.1km) was shorter than for children in the U.S. (37.5km).

Household Life Cycle, Employment and Travel Distance

Exhibit 9.8 shows that, for every household life cycle category, unemployed individuals traveled less than employed individuals. In the U.S., employed adults in households with children traveled the greatest number of kilometers by car per day. In Germany employed adults in households with and without children traveled the most kilometers per day.

Exhibit 9.8 Average Kilometers of Daily Car Travel by Household Composition and Employment Status



(Data: respondents who drive and travel fewer than 200km by car per day)

9.1.2.4 Differences in Macro-Economy

As explained above differences in macro-economic conditions were difficult to measure on the level of the individual. The only potential variable available compared travel behavior on Sundays to weekdays. This was of course a very rough proxy for macro-economic differences. Germans traveled 36.1km on Sundays, compared to 32.8km on other days of the week. If Germans made a car trip on the weekend, then that trip was longer than a car trip during the week. Americans traveled slightly fewer kilometers on Sundays compared to other days of the week (51.1km on weekends compared to 50.0km on weekdays). This variable might be more relevant in explaining difference in the probability of making a car trip for the Heckman Selection Model (HSM). It was included in the multivariate analysis as it makes theoretical sense to control for macro-economic differences.

Proxy for other National Differences U.S. – Germany Dummy Variables

A dummy variable simply identified German and American respondents (1=Germany, 0=US). The sample included 59.9 percent U.S. respondents and 40.6 percent German respondents. Americans traveled 50.9km per day compared to only 33.1km for Germans.

9.1.3 Bivariate Correlations

Table 9.5 below presents bivariate correlations between all variables that were included in the multivariate analysis. All bivariate correlations were statistically significant, with only a few independent variables correlated higher than the absolute value of 0.3 (indicated with an underscore). Such correlations were found between operating costs per kilometer, relative speed, car ownership, density, transit access, and the Germany dummy variable. Of special concern were the correlations of operating cost, relative speed, and the Germany dummy, which were at or above the absolute value of 0.53. The high correlations with the Germany dummy could especially cause problems in the form of inefficient estimators, which could affect magnitude and sign of the coefficients of the correlated variables. Estimators of non-correlated variables were not affected, however. The cost variable and the Germany dummy were theoretically important variables for this analysis, and therefore remained in the model.[121]

Other correlations above 0.3 suggested that households in denser areas had better transit access and generally owned fewer automobiles. Furthermore, Germans lived generally in denser settlements and owned fewer cars than Americans.[122] The correlations for the variable Sunday were very low (almost 0) for all variables and only two of its correlations were statistically significant at the 0.01 level. As expected the variable identifying children and whether the individual holds a driver's license or not were also highly correlated.

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[121] Tests for multicollinearity were carried out. If multicollinearity was a problem two solutions exist. First, the correlated variables were eliminated from the pooled analysis. Second, two separate models, one for Germany and one for the U.S. were estimated. The coefficients and standard errors of the variables in question could be compared to the pooled sample. If they were consistent, then the influence of multicollinearity was minor and the pooled sample wass preferred. Separating the data for the two countries eliminated the Germany dummy, however. Combining the two variables through principal component analysis was not an option, as this dissertation is interested in the unique contribution of cost and the Germany dummy.

[122] The correlations between the independent variables were not considered high. One strategy to dissolve correlation among independent variables would be to build factors of independent variables using factor analysis (or principal component analysis, a special case of factor analysis). Unfortunately, the correlated variables all fell into different categories of variables: transit access was a policy variable, population density related to spatial development patterns, car ownership fell into socioeconomics and the Germany dummy variable measured culture. An attempt was made to reduce the number of independent variables via principal component analysis. Unfortunately, the variables from different categories fell into similar components (e.g. car ownership together with transit access and density). For interpretation purposes the variables were left unchanged.

Table 9.5 Bivariate Correlations for Independent and Dependent Variables

	Distance of Car Travel	Transit Access <400	Transit Access 400-1000m	Operating Cost per km	Relative General-ized Costs	Density	Mix	Income	Car Access	Driver's License	Kid / teenager	with job in single HH	w/o job in single HH	with job in couple HH	w/o job in couple HH	with job in HH with child <6	w/o job in HH with child <6	w/o job in HH with child 6-16	retired HH
Distance of Car Travel	1.00																		
Transit <400	-0.12	1.00																	
Transit 400-1000m	-0.08	*-0.42*	1.00																
Operating Cost per km	-0.21	*0.18*	0.26	1.00															
Relative Generalized Costs	*0.58*	*-0.17*	-0.15	*-0.55*	1.00														
Density	-0.19	*0.40*	0.16	*0.44*	*-0.31*	1.00													
Mix	-0.07	0.06	-0.01	0.03	-0.08	0.05	1.00												
Income	0.10	-0.06	0.00	-0.15	0.26	-0.07	-0.03	1.00											
Car Access	0.16	-0.19	-0.11	-0.35	0.27	*-0.30*	-0.04	0.23	1.00										
Driver's License	0.16	0.01	0.01	0.03	0.07	0.01	0.02	0.00	0.04	1.00									
Kid / teenager	-0.13	-0.05	-0.02	-0.08	-0.03	-0.07	-0.02	0.07	0.08	*-0.86*	1.00								
with job in single HH	0.03	0.02	-0.01	-0.05	0.03	0.03	0.04	-0.12	0.10	0.10	-0.10	1.00							
w/o job in single HH	-0.01	0.01	0.00	0.00	-0.02	0.01	0.01	-0.09	-0.02	0.02	-0.04	-0.01	1.00						
with job in couple HH	0.08	0.00	-0.02	-0.08	0.13	-0.03	0.01	0.12	0.04	0.20	-0.21	-0.08	-0.03	1.00					
w/o job in couple HH	-0.04	0.03	0.04	0.11	-0.09	0.07	0.01	-0.04	-0.08	0.07	-0.11	-0.04	-0.02	-0.09	1.00				
with job in HH with child <6	0.07	-0.02	-0.01	-0.06	0.07	-0.02	-0.01	0.03	0.02	0.15	-0.16	-0.06	-0.02	-0.13	-0.07	1.00			
w/o job in HH with child <6	-0.01	0.00	0.01	0.02	-0.04	0.02	-0.01	-0.03	-0.04	0.07	-0.09	-0.03	-0.01	-0.07	-0.04	-0.05	1.00		
w/o job in HH with child 6-16	-0.02	0.01	0.02	0.05	-0.06	0.01	-0.01	0.00	-0.04	0.07	-0.10	-0.04	-0.01	-0.09	-0.04	-0.06	-0.04	1.00	
retired in retired HH	-0.04	0.02	0.01	0.09	-0.09	0.04	0.02	-0.19	-0.13	0.17	-0.25	-0.10	-0.04	-0.21	-0.11	-0.16	-0.09	-0.10	1.00
Male/ female	0.05	0.01	0.01	0.05	0.04	0.02	0.00	0.03	0.01	0.04	0.01	0.01	-0.02	0.05	-0.05	0.04	-0.13	-0.07	0.00
Sunday*	0.01	0.00	-0.02	-0.04	0.05	0.00	0.00	-0.01	0.00	-0.02	0.02	0.00	0.01	0.00	0.00	0.00	-0.01	0.01	0.01
Germany/USA	-0.22	0.21	*0.30*	*0.89*	*-0.53*	*0.47*	0.03	-0.17	-0.40	0.04	-0.10	-0.05	0.00	-0.08	0.13	-0.06	0.02	0.05	0.07

if not inicated differently: all correlations significant at 0.01 level (two tailed)

*For variable Sunday: only correlations with transit distance, Germany/US dummy, and distance traveled are significant at 0.05 level (two tailed)

(Data: respondents who drive and travel fewer than 200km by car per day)

9.1.4 Findings from Bivariate Analysis

Almost all variables had the expected relationships with the dependent variable. The only exception was the size of the metropolitan area, which did not have an influence on daily car travel distance in this particular sample; and longer car travel distances on Sundays compared to the rest of the week for Germany. For all variables, the U.S. displayed greater distances of car travel than Germany for all categories of the independent variables.

As in Chapter 8, the relationship between travel distances by car by wealthier Germans compared to the poorest Americans called into question the theoretical relationship between travel distance and income. As this unexpected relationship has been reinforced with this example, it is necessary to examine other variables to understand what governs the decision making process in both countries.

Similarly, Americans living at population densities of over 5,000 people per km^2 traveled about as many kilometers by auto per day as Germans at population densities of less than 1,000 people per km^2. This was contrary to expectations, as theory would suggest that similar people in similar spatial settings should display similar travel behavior, everything else equal. If this held true, Germans living at lower population densities than their American counterparts would be expected to travel more. The theory of shorter car travel distances with increasing population density held true again for both countries, but could not explain differences in travel *between* the countries. The multivariate regression analysis in the next section sheds more light on difference in travel controlling for other explanatory factors.

9.2 Multivariate Analysis: Linear Regression with and without Interaction Effects for Daily Car Travel Distances of less than 200km

The dependent variable for the models presented in this section was total daily car travel distance per person. The variable was truncated at 200km and the sample included only individuals that made a car trip on the travel day.[123,124] The independent variables captured transportation policies, spatial development patterns, socioeconomic, and demographic variables. Furthermore, proxy variables for macro-economic differences and cultural preferences were included. In contrast to the bivariate analysis above, the regression coefficients controlled for the independent effects of each variable, holding the influence of the other variables constant. An overview of the levels of measurement and ranges of the dependent and independent variables was provided in Table 9.6 below.

[123] The analyses presented excluded all daily travel distances of over 200km. As discussed earlier in the chapter, another possibility to overcome the problems of a skewed distribution with outliers was to take the natural logarithm of the variable. This transformation compressed the outliers more than the smaller values and resulted in a more normally distributed dependent variable. These models were presented in the appendix. Signs of coefficients for statistically significant independent variables were the same as for the truncated model above, as are the results of the overall F-tests. The R^2 reached 13 percent.

[124] Another modeling approach would include non-car trip makers with a daily car travel distance of 0. A set of models was estimated and is presented in the appendix. For these models individuals that did not make a trip were assigned operating costs of cars in their household (if available). The sign and strength of most coefficients did not change considerably. The coefficients for driver's were stronger indicating that individuals without a license are less likely to make a car trip. The coefficient for car ownership per household member was also stronger. Car access might be encouraging car use. Finally, the Germany dummy was about twice as large as in the model excluding non-car trip makers. This was most likely related to the higher share of Germans that do not travel by car during a travel day; they were excluded from the initial model. The R^2 for the model including 0km of car distance reached 17 percent.

Table 9.6 Dependent and Independent Variables used in Multivariate Regression Analysis

		Level of Measurement	Mean	Min	Max	N
Dependent variable						
	Car travel distance	interval ratio	43.8	0	200	76,094
Independent variables						
Policy	Transit access <400m	nominal/dummy (1= hh within 400m of transit stop)	*n.a.*	0	1	75,867
Policy	Transit access 400-1000m	nominal/dummy (1= hh within 400-1000m of transit stop)	*n.a.*	0	1	75,867
Policy	Operating cost per km in cent	interval ratio	*6.40*	1.3	19.1	73,292
Policy	Relative generalized cost of other modes vs. car	interval ratio	*3.80*	1.4	6.4	76,094
Spatial development patterns	Population density (pop. per sqkm)	interval ratio	1,603	0.1	9,979	75,379
Spatial development patterns	Mix of use	interval ratio	0.33	0.01	9.99	75,355
Socioeconomic and demographic variables	Household Income	interval ratio	55,160	2,500	115,000	73,109
Socioeconomic and demographic variables	Car access/availability	interval ratio	0.98	0	4	76,071
Socioeconomic and demographic variables	Driver's license	nominal/dummy (1=respondent has driver's license)	*n.a.*	0	1	74,660
Socioeconomic and demographic variables	Younger than 16/18	nominal/dummy (1=respondent younger than driving age)	*n.a.*	0	1	74,660
Socioeconomic and demographic variables	Employed in single HH	nominal/dummy (1=respondent with job in single HH)	*n.a.*	0	1	74,660
Socioeconomic and demographic variables	Unemployed in single HH	nominal/dummy (1=respondent without job in single HH)	*n.a.*	0	1	74,660
Socioeconomic and demographic variables	Employed in adult only HH	nominal/dummy (1=respondent with job in 2 pers. HH)	*n.a.*	0	1	74,660
Socioeconomic and demographic variables	Unemployed in adult only HH	nominal/dummy (1=respondent without job in 2 pers. HH)	*n.a.*	0	1	74,660
Socioeconomic and demographic variables	Employed in HH with small children	nominal/dummy (1=respondent with job in HH with child 0-5)	*n.a.*	0	1	74,660
Socioeconomic and demographic variables	Unemployed in HH with small children	nominal/dummy (1=respondent without job in HH with child 0-5)	*n.a.*	0	1	74,660
Socioeconomic and demographic variables	Unemployed in HH with school children	nominal/dummy (1=respondent without job in HH with child 6-16/18)	*n.a.*	0	1	74,660
Socioeconomic and demographic variables	Retired HH	nominal/dummy (1=respondent retired in retired HH)	*n.a.*	0	1	74,660
Socioeconomic and demographic variables	Sex (Male=1)	nominal/dummy (1=male)	*n.a.*	0	1	76,094

(Data: respondents who drive and travel fewer than 200km by car per day)

Table 9.7 below shows the first set of five nested models. Model 1 included the first two policy variables measuring the distance of the respondent's household to public transportation and cost per kilometer driven. Model 2 added two variables capturing spatial development patterns: population density and mix of land use. Model 3 then added socioeconomic and demographic variables. These included car ownership per household member of driving age, household income, license holders, gender, and a set of dummy variables for the household life cycle. The reference category for the life cycle dummy variables was an employed adult in a household with school children. Model 4 added a dummy variable contrasting Sundays with the rest of the week. This served as rough proxy for macro-economic differences. Finally, Model 5 added a dummy variable, identifying if the respondent resided in Germany or the U.S. This variable captured differences between the two countries not explained by variables included earlier.

All signs were in the expected direction and most coefficients were significant at the one percent level. Sequentially adding groups of variables traced changes in coefficients' magnitude, significance, and sign. This helped detect omitted variable bias and multicoliniarity. For example, the coefficient for operating cost of car travel changed significantly once the Germany/U.S. dummy was included in the model. Model 5 was the preferred model, as it included all theoretically relevant variables.

Table 9.7 Dependent Variable: Daily Car Travel Distance per Person in km

		Model 1	Model 2	Model 3	Model 4	Model 5
	Constant	**64.862**	**68.365**	**56.257**	**56.049**	**54.374**
		(130.84)**	(118.61)**	(46.50)**	(46.41)**	(44.11)**
Policy	Transit access <400m	**-10.41**	**-6.567**	**-6.279**	**-6.279**	**-5.991**
		(22.31)**	(12.81)**	(12.08)**	(12.09)**	(11.50)**
	Transit access 400-1000m	**-8.398**	**-5.906**	**-5.755**	**-5.75**	**-5.226**
		(15.33)**	(10.42)**	(10.03)**	(10.03)**	(8.96)**
	Operating Cost per km of Car Travel	**-2.332**	**-1.975**	**-1.763**	**-1.757**	**-1.155**
		(34.08)**	(27.38)**	(22.90)**	(22.83)**	(8.48)**
Spatial development patterns	Population density		**-2.457**	**-2.364**	**-2.368**	**-2.261**
			(15.27)**	(14.25)**	(14.28)**	(13.54)**
	Mix of use		**-12.167**	**-12.209**	**-12.22**	**-12.298**
			(12.79)**	(12.63)**	(12.65)**	(12.73)**
Socioeconomics and demographics	Household Income			**0.074**	**0.074**	**0.071**
				(9.28)**	(9.30)**	(8.84)**
	Car access/availability			**4.148**	**4.15**	**3.734**
				(8.81)**	(8.81)**	(7.83)**
	Driver's License			**5.716**	**5.749**	**5.851**
				(8.32)**	(8.39)**	(8.56)**
	Younger than 16/18			**-13.637**	**-13.619**	**-13.707**
				(17.36)**	(17.34)**	(17.48)**
	Single HH with Job			**0.632**	**0.633**	**0.467**
				(0.69)	-0.69	(0.51)
	Single HH without Job			**-3.999**	**-4.028**	**-4.297**
				-1.61	-1.62	-1.73
	Couple HH with Job			**0.384**	**0.386**	**0.227**
				-0.65	-0.66	(0.39)
	Couple HH without Job			**-5.646**	**-5.658**	**-5.551**
				(6.78)**	(6.79)**	(6.67)**
	HH, Small Children with Job			**2.518**	**2.521**	**2.315**
				(3.60)**	(3.60)**	(3.31)**
	HH, Small Children without Job			**-3.695**	**-3.688**	**-3.805**
				(3.77)**	(3.76)**	(3.89)**
	HH, Older Children without Job			**-5.31**	**-5.325**	**-5.366**
				(6.53)**	(6.54)**	(6.60)**
	Retired HH			**-5.18**	**-5.176**	**-5.408**
				(9.33)**	(9.33)**	(9.69)**
	Sex (Male=1)			**4.026**	**4.019**	**3.966**
				(14.85)**	(14.83)**	(14.62)**
	Sunday				**1.113**	**1.072**
					(1.60)	(1.54)
	Germany(1/0)					**-4.635**
						(5.38)**
	Observations	**73070**	**72030**	**69302**	**69302**	**69302**
	R-squared	**0.06**	**0.06**	**0.11**	**0.11**	**0.11**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%					

(Data: respondents who drive and travel fewer than 200km by car per day)

Living closer to transit, at a higher population density, and in a neighborhood with greater mix of land uses reduced daily car travel distances. For example, living within 400m of a transit stop compared to households more than 1000m from a transit stop, reduced individual daily car travel distance by 5.9km. As expected, the magnitude of this effect was less for the intermediate distances: individuals living between 400m and 1000m from a transit stop traveled 5.2 fewer kilometers by car than those living farther away.

Higher operating costs per kilometer decreased daily car travel distance. A one cent increase in operating costs per kilometer decreased daily car travel distance by 1.2km. At the averages of operating costs per km and distance traveled, one cent represented a 15.6 percent increase in operating cost and a 2.8 percent decrease in kilometers of car travel. This represented a price elasticity of demand of |0.18| for automobile travel. This finding was in line with elasticities of demand for fuel and kilometers of travel found in the literature (DeJong & Gunn, 2001; Epsey, 1998; Hanly et al., 2002; Litman, 2007).[125]

The magnitude of the effect of the policy variables changed between Models 1 and 2 and between Models 4 and 5. Including population density and mix of use in Model 2 reduced the magnitude of transit distance and operating cost, which suggests that mix of land uses and population density diminished the explanatory power of the policy variables. In general, transit service is most economical at higher population densities

[125] The coefficient for operating costs in Model 5 was considerably lower than for Model 4. This may be a result of collinearity with the Germany dummy. The standard tests for multicollinearity (variance inflation factor (VIF), condition index, and tolerance) were carried out, but no significant multicollinearity could be detected. The average VIF was 1.7, with cost per kilometer at 4.6 and the Germany dummy at 5.16. Average values of above five are considered critical. The condition index reached 17.5 for the U.S. Germany dummy; values above 30 are considered critical. The Germany dummy also displayed the lowest tolerance value at 0.19. Values below 0.1 are considered critical.

and car driving is often not necessary in mixed land use areas. When the country dummy variable was included in Model 5 the coefficients of the policy variables decreased again. The difference between Germany and the U.S. helped explain some of the variability in car travel distance, which had previously been attributed to the policy variables. The dummy variables—though capturing the residual—arguably represented a set of policies and other factors not included in the models.

Higher incomes and easy access to an automobile led to increased daily car travel distance. One additional car per household member increased daily car travel distance by 3.7km. Children and teenagers not yet at driving age traveled 13.7km less by car than employed adults in households with school children. Men traveled 4km more per day than women. The Sunday dummy variable was not significant at the five percent level in Model 5 and indicated 1.1km greater daily car travel distance for Sundays.[126] Finally—as expected—being in Germany and not in the U.S., was connected to shorter travel distances (4.6 fewer km).

Model Fit

The F-tests assessing the joint significance of all independent variables were statistically significant, which indicated that the effect of at least one independent variable in each model was statistically different from zero. Total variance explained by the independent variables increased for each added variable[127] and reached 11 percent for the last model. These R^2s were in line with other multivariate analyses performed on

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[126] One explanation might be that individuals, who decide to use a car on Sunday's, might go as far, or even farther than during weekdays. This variable might be a better indicator if individuals made a car trip on the travel day or not.

[127] Only marginally for the spatial development variables, and the dummy variables for Sunday and Germany/U.S., however.

NHTS and MiD[128], reflecting the disaggregate nature and the degree of variability of the individual level data found in the national travel surveys.

The final model explained 11 percent of total variability in travel distance. Based on the sequential changes in R^2 as variables were added, the variance explained was distributed as follows: 54 percent of the total variance explained could be attributed to the policy and spatial development variables (0.06 of 0.11 of variability explained) and 46 percent for socioeconomic and demographic variables (0.05 of 0.11). This interpretation of course depends on the order in which the variables were entered and the order might bias the percentage of explanatory power attributed to each group of variables. Alternatively, five models each including a single group of independent variables were estimated. These models showed the variance explained uniquely by each group of variables. These models are presented in the Appendix. The R^2s for each individual group of independent variables were: six percent for the transportation policies; four percent for spatial development patterns; six percent for socioeconomic and demographic variables; 0 percent for the Sunday dummy; and four percent for the Germany/U.S. dummy variable.

The regressions so far have identified the sign, magnitude, and significance of the independent variables in the pooled sample, but have not captured differences in coefficients between Germany and the U.S. Table 9.8 below displays results of nested models with interaction effects for Germany for every independent variable, which captured the relative strength of the variables in each country.

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[128] E.g. The final models Giuliano et al. (2003, 2006) estimated had R^2s ranging from 9.6 percent to 16 percent .

Again all signs were in the expected direction, but not all were significant. The preferred model was Model 5 as it included all statistically significant independent variables. The interpretation of specific coefficients below was based on Model 5 if not otherwise indicated.

Table 9.8 Dependent Variable: Daily Car Travel Distance per Person in km (Model with Interaction Effects)

		Model 1	Model 2	Model 3	Model 4	Model 5
Policy	Transit access <400m		**-11.643** (19.73)**	**-6.94** (9.74)**	**-6.815** (9.37)**	**-6.815** (9.36)**
	Transit access <400m G		**7.783** (7.71)**	**4.667** (4.27)**	**4.747** (4.34)**	**4.737** (4.33)**
	Transit access 400-1000m		**-8.252** (9.55)**	**-5.652** (6.35)**	**-5.695** (6.20)**	**-5.689** (6.19)**
	Transit access 400-1000m G		**5.607** (4.65)**	**3.753** (3.06)**	**3.672** (2.97)**	**3.691** (2.98)**
	Operating cost per km of car travel		**-2.733** (11.31)**	**-2.772** (11.47)**	**-2.753** (11.01)**	**-2.757** (11.02)**
	Operating cost per km of car travel G		**2.077** (6.76)**	**2.308** (7.52)**	**2.278** (7.24)**	**2.291** (7.28)**
Spatial development patterns	Population density			**-2.721** (11.03)**	**-2.658** (10.31)**	**-2.656** (10.29)**
	Population density G			**1.209** (3.66)**	**0.983** (2.88)**	**0.954** (2.79)**
	Mix of use			**-13.226** (11.51)**	**-13.225** (11.26)**	**-13.217** (11.25)**
	Mix of use G			**-0.406** (0.19)	**0.28** (0.13)	**0.282** (0.13)
Socioeconomic and demographic variables	Household income				**0.06** (6.63)**	**0.06** (6.62)**
	Household income G				**0.039** (2.13)*	**0.039** (2.14)*
	Car access/availability				**3.098** (5.52)**	**3.095** (5.51)**
	Car access/availability G				**3.541** (3.45)**	**3.584** (3.50)**
	Driver's License				**6.62** (6.49)**	**6.599** (6.47)**
	Driver's License G				**-1.325** -0.98	**-1.152** -0.86
	Younger than 16/18				**-16.071** (14.53)**	**-16.08** (14.53)**
	Younger than 16/18 G				**6.633** (4.31)**	**6.73** (4.38)**
	Sex (Male=1)				**3.76** (9.58)**	**3.765** (9.59)**
	Sex (Male=1) G				**1.132** (2.13)*	**1.095** (2.06)*

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Socioeconomic and demographic variables	Single HH with job				**-2.619** (2.22)*	**-2.619** (2.22)*
	Single HH with job G				**7.784** (4.13)**	**7.792** (4.13)**
	Single HH without job				**-9.835** (2.72)**	**-9.82** (2.72)**
	Single HH without job G				**12.571** (2.52)*	**12.372** (2.49)*
	Couple HH with job				**-1.171** (1.43)	**-1.171** (1.43)
	Couple HH with job G				**2.87** (2.50)*	**2.888** (2.51)*
	Couple HH without job				**-5.712** (3.23)**	**-5.689** (3.22)**
	Couple HH without job G				**1.896** (0.96)	**1.851** (0.93)
	HH, small children with job				**2.384** (2.48)*	**2.383** (2.48)*
	HH, small children with job G				**-2.203** (1.62)	**-2.179** (1.61)
	HH, small children without job				**-4.651** (3.07)**	**-4.652** (3.07)**
	HH, small children without job G				**1.972** (1.02)	**2.017** (1.04)
	HH, older children without job				**-6.546** (4.86)**	**-6.536** (4.85)**
	HH, older children without job G				**3.116** -1.89	**3.044** -1.85
	Retired HH				**-9.182** (10.71)**	**-9.187** (10.72)**
	Retired HH G				**7.998** (7.19)**	**8.012** (7.21)**
Macro-economic differences	Sunday					**-0.926** (0.99)
	Sunday G					**4.967** (3.64)**
	Germany(1/0)	**-18.086** (48.34)**	**-24.021** (11.91)**	**-24.052** (11.37)**	**-30.55** (10.98)**	**-31.345** (11.27)**
	Constant	**51.357** (186.31)**	**67.551** (61.76)**	**72.952** (62.81)**	**64.906** (36.68)**	**65.071** (36.82)**
	Observations	**72827**	**72605**	**71565**	**68840**	**68840**
	R-squared	**0.05**	**0.06**	**0.07**	**0.11**	**0.11**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%					

(Data: respondents who drive and travel fewer than 200km by car per day)

For all models, Germans traveled fewer kilometers by car per day than Americans. Simply being in Germany and not the U.S. decreased daily car travel distance by 31.3km in Model 5. Living within 400m of a transit stop reduced daily travel distance by 6.8km in the U.S., but only by 2.1km in Germany.[129] Living between 400m and 1000m from a transit stop compared to greater distances decreased daily travel by slightly fewer kilometers (5.7km in the U.S. and 2.0km in Germany).

A one cent increase in the operating cost of the car led to a 2.8km reduction in car kilometers traveled. Surprisingly, in Germany, the reduction was much lower at 0.5km. The magnitude of these coefficients was unexpected, as theory would suggest a more elastic demand in Germany given higher gasoline prices, better accessibility without a car, and greater availability of other modes of transportation there. A closer look at these results showed that the differences were not as pronounced as they might seem at first sight and that these results were in line with prior research.

First, at the mean a one cent increase in driving cost constituted a 23.1 percent increase in the U.S., compared to only 10.3 percent in Germany.[130] At the mean, the reduction in daily kilometers of car travel was 5.5 percent in the U.S. and 1.5 percent in Germany. Price elasticities of demand for passenger kilometers of car travel were |0.24| for the U.S. and |0.15| for Germany.[131] In other words: A 10 percent increase in operating costs of car reduced passenger kilometers of car travel by 2.2 percent in the U.S. and by 1.6 percent in Germany. The 95 percent confidence intervals for the two

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[129] The effect for Germany was the *sum* of the U.S. coefficient and the Germany interaction coefficient for transit distance (-6.8+4.7=-2.1). In other words the interaction effect for Germany indicated the *difference* in slope between the two countries.

[130] Taking differences in fuel efficiency in the two countries into account, a one cent increase in operating cost per kilometer was the equivalent of an increase in gas price of nine cents per liter (34 cents per gallon) in the U.S. and an 11 cent increase per liter in Germany (41.6 cents per gallon). In 2001/2002 the price of a liter of gasoline was $0.39 in the U.S. ($1.47 per gallon) and $1.07 in Germany ($4.04 per gallon).

[131] Calculated by dividing 5.5 by 23.1 for the U.S. and 1.5 by 10.3 for Germany.

elasticity estimates overlapped: ranging from |.08| to |.26| for Germany and |.18| to |.26| for the U.S. Thus it could not be determined that the two estimates were statistically significantly different.

Second, more inelastic demand for driving in Germany compared to the U.S. was in line with findings from Litman (2007) and DeJong (2005). They reported lower price elasticities of demand for kilometers of car travel in Europe compared to the U.S. It is possible that as a reaction to historically high gasoline prices, Germans might already have minimized driving. Further increases in the price of gasoline will result in smaller reductions in kilometers of travel as the car trips currently made were necessary and hard to substitute or forego. In the U.S., gasoline prices have traditionally been low and most trips were made by car. If gas prices increase, individuals could more easily forego unnecessary car trips, thus leading to a reduction in driving. Germans might also potentially substitute gasoline powered cars for diesel cars that are much more energy efficient—thus leading to a smaller decrease in travel distance as price of gas increases.

Higher population density and greater mix of land use led to shorter daily travel distance by car. For population density this effect was significantly weaker for Germany than for the U.S. While an additional 1,000 people per km^2 led to a 2.7km shorter daily travel distance in the U.S., the reduction was 1.8km in Germany.

An additional car per household member of driving age led to an average increase in daily car travel distance of 3.1km in the U.S. This effect was twice as strong in Germany: each additional car led to an increase in daily car travel distance of 6.7km.

Higher household incomes led to more kilometers of daily car travel in both countries. The effect of income after controlling for car ownership and access was small, however. A $10,000 increase in household income led to a 0.6km increase in daily car travel distance in the U.S. For Germany this effect was stronger, but still small (1km) given the increase in income. This result suggested that access to a car may influence car travel distance more than a household's income level or relative ability to pay for certain types of trips.

Men traveled 3.8km more by car than women in the U.S. and 4.9km more in Germany. In the U.S., individuals with a driver's license traveled 6.6km more by car than individuals without a license. This effect was slightly smaller in Germany, where the difference was 5.5km.

The reference category for the household life cycle variables was an employed adult in a household with school children. First, in both countries and in every household life cycle category, unemployed adults traveled fewer kilometers by car than the reference category. Second, in Germany employed individuals in households without children traveled a greater number of kilometers than the reference category. Third, in the U.S., households with children traveled more than households without children. Fourth, in both countries employed adults in households with small children traveled more than the reference category. Fifth, retirees traveled fewer kilometers in both countries (-9.2km in the U.S., but just -1.1km in Germany).

Model 5 showed finally, that car travel distances on Sunday were shorter in the U.S., but significantly longer in Germany. One explanation might be that Germans who decided to travel by car on Sunday traveled farther distances than during the week, perhaps for excursions, to see family, friends, or for recreational trips. Similar to retirement status, it was expected that the likelihood of making a car trip on Sunday was lower in Germany compared to the U.S. This will be investigated further in the HSM model presented below.

Groups of independent variables were added sequentially to the models. The F-statistics for all models were significant, indicating that the effect of at least one of the variables was statistically not equal to zero and the independent variables had joint statistical significance in explaining the dependent variable. As each set of variables was added to the model, the change in the R^2 explained the relative impact of that set on car distance traveled. Transportation policy variables together with the country dummy explained five percent of the variability in the pooled sample. Spatial development patterns added another one percent to the R^2. Socioeconomic and demographic variables added another four percent to the R^2. The Sunday dummy only increased the R^2 marginally, so the overall R^2 stayed at 11 percent. Deconstructing the total variability into the different components yielded: 54 percent explained by the policy and the dummy variable (0.06 out of a total of 0.11), nine percent by spatial development variables (0.01 of 0.11), and 36 percent by socioeconomic and demographic variables (0.04 of 0.11).

As in the previous set of models, the sequential approach had to be carefully interpreted as the variance explained depended on the order in which variables were entered.[132] Models of each set of independent variables were estimated to identify the variance explained uniquely by each group of variables and were presented in the appendix. To summarize these models, the R^2 for each set of independent variables were: six percent for transportation policies; six percent for spatial development patterns; nine percent for socioeconomic and demographic variables; five percent for the Sunday

[132] As explained in Chapter 8, the analysis of the interaction effects necessitated the inclusion of the Germany/U.S. dummy variable. Therefore, the interpretation of R^2 might be misleading, as it reflects the percentage of variability explained by the dummy variable *and* the policy variables.

dummy. For modeling purposes, all groups of variables already included the Germany/U.S. dummy variable.

The standard tests for multicoliniarity (Variance Inflation Factor (VIF), Tolerance and Condition Index) yielded the following results. The overall VIF was 7.6, which falls above the critical value of 5. It was pulled up by the two highly correlated variables of operating cost per kilometer driven and the Germany dummy—both with individual VIF of over 40. The Tolerance and the Condition Index yielded similar results (Tolerance was lower than 0.1 for operating cost per kilometer and the country dummy). These results implied that the coefficients for cost per kilometer and the Germany dummy might be statistically inefficient estimators affecting magnitude, sign, and standard errors. To control for multicoliniarity between cost per kilometer driven and the country dummy two separate models were estimated—one for Germany and one for the U.S. In the separate models all multicoliniarity indicators were satisfactory.

The coefficients for the operating cost and all other variables were almost identical to the ones in the pooled model presented above. Consequently the coefficient, sign, and magnitude of the operating cost variable were not affected by multicoliniarity in the joint model. It was therefore concluded that the coefficients for all variables except the dummy could be considered reliable in the joint model. Results for the separate models were shown in the Appendix.

Given the nature of the household-based survey data, spatial autocorrelation can also cause inefficient estimators. Multiple regression models assume that errors are uncorrelated, but these datasets presented some challenges to this assumption. For example, respondents in the same household faced the same characteristics on variables such as household income or car access, and respondents within the same neighborhood, city, or state faced similar transportation policies and supply conditions. Therefore the observations and resulting errors were not uniquely independent. The statistical package STATA allowed the estimation of coefficients and errors that were robust to spatial autocorrelation. Two such models were estimated and it was found that results did not change significantly. The adjusted standard errors and coefficients accounted for clustering of respondents by household, neighborhood and city, as well as by state.

9.2.1 Extension: Two-Stage Model Controlling for Selection Bias

The regression analyses so far included only individuals who made a car trip on the travel day.[133] As discussed above, these estimates could be biased due to selection—implying that individuals who made a car trip were significantly different from those who did not choose to travel by automobile. If there was selection bias, then modeling only the car trip distance could lead to inconsistent coefficients. Furthermore, it could be argued that a one-stage model on car trip distance omits an important part of the travel decision making process. In a first stage individuals decide if they make a car trip or not. Then, only if a car trip is made, individuals decide how far to travel. Therefore a two-stage model would be more appropriate for capturing real world car trip decision making than a one-stage model.[134]

[133] One set of models in appendix eight included individuals who did not make a car trip with 0km distance, however.

[134] Heckman Selection Models (HSM) allow modeling such a two-stage process. HSM in the first stage uses a probit regression to determine if individuals made a car trip on a travel day or not. In a second stage HSM models the car trip distances for those individuals who were traveling on the travel day. The model specification allows correlation between variables and errors of stage one and stage two (Kennedy, 2003; Xinyu et al., 2006). The two equations are estimated simultaneously taking the correlation of variables and errors into account. In practice it is common to use at least one variable that is the same in both stages of the modeling and at least one variable that is different in both stages (Kennedy, 2003; Xiny et al., 2006). This is appropriate for this analysis as similar variables help explain the choice to make a trip and travel

Variables included in the first stage of the model were socioeconomic variables, the *Sunday* variable, and relative speed of other modes compared to the car. It was expected that individuals were less likely to make a trip on Sundays, compared to weekdays. Furthermore, it was expected that the elderly and individuals who lived close to a transit stop were less likely to make car trips. Furthermore, it could be argued that the relative speed of the car compared to other transportation modes should be included in the mode choice model. However, relative speed, operating cost per kilometer and the Germany U.S. dummy variable were highly correlated. Therefore, multicoliniarity could be a problem.

A look at the percentage distribution of car trip makers and individuals who did not make a car trip in the sample shows that the variables identified may indeed have given rise to sample selection bias (see Table 9.9 below).

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distance. HSM estimates the linear model on the second equation using a variable accounting for the selection probability from stage one (The so called Inverse Mills-Ratio (IMR), which is—in case of a probit regression in stage one—calculated as (PDF(Beta' X)/CDF(Beta' X)) of the assumed normal distribution). Results of HSMs are very sensitive to model specification, in particular to the correlation of variables and errors between the probit and the linear regression. Therefore a nested modeling approach—where each group of variables is entered into the model separately—is not feasible. Consequently, only one final HSM model was estimated.

Table 9.9 Percent of Respondents not Making a Car Trip on Travel Day

	Germany	**USA**
Average	40.7	19.2
Men	43.1	20.6
Women	38.2	17.7
License	32.3	13.2
No License	59.8	34.4
<0.5 cars per hh member	71.3	59.9
0.5 - 1 cars per hh member	40.9	27.3
1 - 1.5 cars per hh member	28.5	15.5
1.5+ cars per hh member	28.9	14.1
Kid / teenager	52.4	26.5
with job in single HH	37.9	13.2
w/o job in single HH	58.8	44.3
with job in couple HH	29.8	12.0
w/o job in couple HH	45.3	30.4
with job in HH with child <6	25.9	11.5
w/o job in HH with child <6	38.0	24.2
with job in HH with child 6-16	26.3	8.9
w/o job in HH with child 6-16	39.3	26.4
retired in retired HH	52.4	25.3
Sunday	50.6	22.2
Weekdays	39.1	18.7

Unfortunately, the model could not be estimated based on the pooled sample due to high correlation among operating cost, relative speed, and the country dummy variable. Therefore, two separate models were estimated—one for each country. Furthermore the variable driver's license was omitted as it was highly correlated with automobile ownership and household life cycle.

Table 9.10 below shows the HSM results in three columns for each country. Column 1 includes the coefficients for the mode choice model (a probit regression); Column 2 displays the coefficients for the distance models in the second stage of the

HSM; and Column 3 displays marginal changes for car trip making probabilities (as explained in Chapter 8).

The coefficients for the probit models and for the variables included in the distance model can be directly interpreted. As in Chapter 8, the first stage probit results were interpreted by converting the coefficients to marginal effects, i.e., as percentage change in probability of trip making. For example: At the mean, a one unit change in relative speeds of the car compared to other modes of transportation increased the probability of using a car by 10 percent in the U.S. and 20 percent in Germany.[135] Relative speed may have played less of a role in the U.S., because alternative modes may not have been realistic options for many respondents.

Similarly, living within 400 meters of a transit stop decreased the probability of making a car trip by 5.4 percent in Germany but only by 1.9 percent in the U.S. Living within 400 to 1000m of a transit stop did not decrease the probability of car travel. The low sensitivity of travel choices to transit in the U.S. may have reflected the overall weakness of the transit network there, often not linking origins to destinations of trips.

The coefficients and their direction in the car travel distance equation were similar to the linear models presented earlier in this chapter. In both countries, living at a higher population density and in mixed-use neighborhoods led to fewer kilometers of car travel. Higher household incomes led to longer than average daily travel distance by car.

Overall the direction and the strength of the coefficients in stage two were similar to the linear regression models presented above.[136] Some differences between

[135] This interpretation is based on a partial change approach for continuous and on a discrete change approach for dummy variables.

[136] In order to interpret the coefficients shaded in grey, it is necessary to control for multicoliniarity between the two equations and to take the selection probability from stage one into account (Dougherty,

OLS and HSM existed in the magnitude of coefficients of the life cycle dummy variables. While the magnitude changes, the signs of the coefficients and the relative difference between Germany and the U.S. remain roughly the same.

Model fit for HSMs can be assessed using three statistics. The first is an overall Likelihood Ratio test (LR), which tests the null hypothesis that the model is not a good fit. The null hypothesis could be rejected for both models, indicating that the models were a good fit. The second test involved the significance of the estimated selection parameter *rho*. If *rho* is statistically significant, then there is a selection bias and the HSM is an appropriate model. Again the null hypothesis of no selection bias could be rejected for both models, because *rho* was statistically significant. Based on these two tests, the HSM was a good fit. The third test is another LR test using the null hypothesis that there is no selection bias. This test is similar to the t-test for *rho,* but is chi-square distributed. In this case, the null hypothesis could be rejected for both models.

These three statistical tests confirmed that there was a selection bias and that HSM was appropriate. The small changes in coefficients for the HSM compared to the OLS only models, however, indicated that the existing selection bias did not affect the estimation significantly. As this was the case, the OLS models were preferable, since they were straightforward and allowed for a nested modeling structure that controlled for changes in R^2.

2004; STATA Listserve, 2003). The transformed coefficients are given in separate columns labeled "transformed coefficients from Stage 2" in the appendix to this chapter.

Table 9.10 Heckman Selection Model for Mobility Choice and Daily Trip Distance

		Germany			USA		
		STAGE 1	STAGE 2		STAGE 1	STAGE 2	
		Person made a car trip (1/0)	Travel distance	Marginal Change in Car Trip Making Probability at the Mean	Person made a car trip (1/0)	Travel distance	Marginal Change in Car Trip Making Probability at the Mean
Policy	Transit access <400m	**-0.17** (4.28)**		**-5.4%**	**-0.139** (7.02)**		**-1.90%**
	Transit access 400-1000m	**-0.085** (2.64)**		**-2.7%**	**0.059** (1.85)		**0.90%**
	Operating cost per kilometer		**-0.389** (3.26)**			**-2.396** (11.95)**	
	Relative speed of car vs other modes	**0.64** (93.69)**		**19.4%**	**1.088** (72.25)**		**10%**
Spatial development patterns	Population density		**-1.528** (8.72)**			**-3.275** (21.11)**	
	Mix of use		**-9.377** (6.88)**			**-12.118** (13.77)**	
Socioeconomic and demographic variables	HH income		**0.089** (7.35)**			**0.054** (8.12)**	
	Car access	**0.65** (22.14)**		**20.1%**	**0.471** (22.96)**		**14.10%**
	Younger than 16/18	**-0.65** (22.15)**	**-4.118** (5.95)**	**-22.0%**	**-0.647** (19.01)**	**-15.64** (22.93)**	**-17.20%**
	Sex (Male=1)	**0.041** (3.18)**		**0.1%**	**-0.066** (3.66)**		**-0.30%**
	Single HH with job	**-0.138** -1.78	**5.834** (4.08)**	**-4.5%**	**-0.332** (6.19)**	**-1.005** (0.86)	**-7.80%**
	Single HH without job	**-0.271** -1.62	**5.26** (1.58)	**-9.2%**	**-0.648** (5.96)**	**-3.93** (1.13)	**-14.90%**
	Couple HH with job	**0.001** -0.16	**1.224** (1.56)	**0.3%**	**-0.225** (5.56)**	**-0.451** (0.61)	**-1.40%**
	Couple HH without job	**-0.214** (4.01)**	**-1.269** (1.42)	**-7.1%**	**-0.304** (4.55)**	**-4.712** (2.96)**	**-5.30%**
	HH, small children with job	**0.07** (1.74)	**-0.47** (0.49)	**2.0%**	**-0.035** -0.7	**2.343** (2.73)**	**0.40%**
	HH, small children without job	**-0.002** (2.72)**	**-4.007** (3.16)**	**-1.0%**	**-0.124** -1.77	**-5.803** (3.91)**	**-1.40%**
	HH, older children without job	**-0.127** (1.91)	**-1.887** (1.85)	**-4.1%**	**-0.2** (3.36)**	**-5.873** (4.41)**	**-3.40%**
	Retired HH	**-0.113** (2.50)*	**-0.524** (0.82)	**-3.6%**	**-0.105** (2.69)**	**-9.053** (12.07)**	**-3.50%**
	Sunday	**-0.23** (8.13)**		**-7.9%**	**-0.067** (6.20)**		**-1.30%**
	Constant	**-2.58** (58.54)**	**50.909** (36.18)**		**-3.426** (45.92)**	**75.72** (66.90)**	
	Observations	**39951**	**39951**		**44027**	**44027**	
	Likelihood Ratio	-116242.2					
	LR Test (Chi Square(13))	**Prob > Chi Square=0.000**			**Prob > Chi**		
	Rho (Athrho)	**-1.05** (65.93)**			**-1.04** (85.54)**		

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%, coefficients of variables in both models shaded in grey

9.3 Simulations

So far the multivariate analyses have quantified the relative impact of explanatory variables on travel within each country and between the two countries. Using the estimated models' coefficients in simulations can help to capture more of the variability between the countries. The simulations showed how differences in daily car travel distance could change if individuals faced different conditions. The simulations controlled for other variables, by setting them at their average values. Model 5 of the second set of linear models with interaction effects and including non-car trip makers was used for the simulation.[137]

Setting all variables at their mean values yielded an estimated average daily car travel distance of 23.6km for Germany and 46.6km for the U.S. (see Table 9.11 below). These values were close to the actual mean of daily car travel distance for all respondents (including individuals with 0 car trips and truncated at 200km). The difference in daily car travel between an average person in the U.S. and Germany was 49 percent.

Plugging the U.S. mean values into the German equation and the German mean values into the U.S. equation yielded insight into differences in the travel systems. If Germany had the same average *operating costs per kilometer* and *distance to transit* as the U.S. and vice versa, then the difference in kilometers of daily travel would shrink to 15 percent. If the U.S. had Germany's spatial development patterns and vice versa, then the difference in daily car travel would be reduced to 38 percent. If both countries had each other's household income, car ownership, and share of household life cycle stages, then predicted differences in total daily travel distance would fall to 39 percent. Americans would travel fewer kilometers per day by car than Germans (29 percent less), if America and Germany would exchange all their mean values of the variables included

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[137] See appendix for this model. This model was chosen, because it also includes the non-trip makers with a distance of 0km. Alternative simulations for a model for cat-trip makers only are presented in Appendix 9.

in this model, because it would essentially swap all country attributes. The simulation identified the policy variables that are most powerful in influencing car travel behavior.

This initial simulation sequentially changed all variables according to variable groups and then simultaneously. A complete exchange is unrealistic, as Germany and the U.S. would not change in all aspects to become similar. Furthermore, the simulations of full variable sets presented are unrealistic, since they would require significant changes, such as a doubling of average settlement densities in the U.S. The final set of simulations investigated changes in daily car travel distance based on variations of single variables. This type of model more realistically mimicked the impact or potential impact of individual policy changes in either country. All other variables were set at their mean values. Results are summarized in Table 9.11 below.

If operating costs per car would be four cents per kilometer in each country—the current average operating cost in the U.S.—then the difference in daily kilometers of car travel would be 47 percent compared to 49 percent in the base case. If both countries had operating costs of nine cents per kilometer—which reflects the German average cost—then the difference in daily car travel would shrink to only 33 percent. This indicates that transportation pricing policies are important in explaining differences between the countries.

Interestingly, with increasing population densities and mix of land use, Americans and Germans would display diverging car travel behavior. In Germany, daily kilometers of car travel would decrease more rapidly with density and mix of land use compared to the U.S. One explanation might lie in more spread-out land-use patterns outside of the immediate surroundings of a household location in the U.S. Even if the household itself was located in a dense and mix land use neighborhood, low regional densities would require driving.

In both countries higher incomes and easier access to an automobile facilitated car travel. This confirms travel behavior theory, which suggests that higher income groups travel more. Interestingly, the percentage difference in travel between the countries was smaller for richer households and for households with universal car access. One explanation might lie in more spread and economically segregated settlement patterns in the U.S., which necessitate long car trips even by poorer and carless individuals.

Retired Germans traveled 45 percent fewer kilometers by car per day than retired Americans. The reason for this might lie in different developments of mobility in both countries. The elderly in the U.S. today experienced mass-automobile ownership much earlier than the similar German age cohort. Consequently, the model showed this cohort of Americans used the automobile more than their German counterparts. As expected the percentage difference in daily kilometers of car travel was larger between women than men; potentially indicating a more traditional homemaker role for many German women. This might be coupled with lower car ownership rates in Germany. If a car was available then the main bread winner, more likely male in Germany, would use the car to drive to work—leaving the female partner without access to a car. Other simulation results can be read from the table below.

Table 9.11 Simulation Results: Impact of Independent Variables on Difference in Daily Car Travel Distance

Base Case (all variables at their mean)					
	Germany		**USA**		**Difference Germany vs. USA**
All variables at averages	23.6		46.6		49%
Swapped averages (US model with German averages an vice versa)					
	Germany		**USA**		**Difference Germany vs. USA**
Swapped transport policy averages	26.5		31.2		15%
Swapped spatial development pattern averages	26.4		42.4		38%
Swapped socioeconomic and demographic variables	28		45.8		39%
Swapped averages	33.8		26.2		-29%
Effect of Individual Transport Policy Variables					
	Germany		**USA**		**Difference Germany vs. USA**
Transit farther than 1000m, other as base case	26.1		49.3		47%
Transit within 400-1000m, other as base case	23.8		44.1		46%
Transit within 400m, other as base case	22.9		42.8		46%
Operating cost=0.4, other as base case	25.3		47.3		47%
Operating cost=0.6, other as base case	24.7		42.5		42%
Operating cost=0.9, other as base case	23.8		35.3		33%
Effect of Individual Spatial Development Pattern Variables					
	Germany		**USA**		**Difference Germany vs. USA**
Density=1000, other as base case	26.3		46.9		44%
Density=2500, other as base case	23.7		42.8		45%
Density=5000, other as base case	19.2		36		47%
Mix of use=0.25, other as base case	24.6		47.5		48%
Mix of use=0.5, other as base case	21.9		44.3		51%
Mix of use=0.75, other as base case	19.2		41.1		53%
Effects of Individual Socioeconomic and Demographic Variables					
	Germany		**USA**		**Difference Germany vs. USA**
Cars per HH member= 0.5, other as base	16.8		43.4		61%
Cars per HH member= 0, other as base	21.9		44.9		51%
Cars per HH member= 1, other as base	26.9		46.4		42%
Cars per HH member= 1.5, other as base	31.9		47.9		33%
HH income= 10,000, other as base case	20.3		43.5		53%
HH income= 35,000, other as base case	22.5		45.2		50%
HH income= 75,000, other as base case	26		47.8		46%
Child/teenager=1, other as base case	17.2		34.7		50%
Female=1, other as base case	21.8		45.2		52%
Female=0, other as base case	25.5		48.3		47%
Retired=1, other as base case	21.9		39.5		45%
License=1, other as base case	26.7		49.8		46%
License=0, other as base case	16.4		38.8		58%

9.4 Conclusion

The bivariate and multivariate analyses and simulations yielded consistent results concerning most stated hypothesis. Living closer to a transit stop, at higher population densities, and in areas with a high mix of land uses implied a lower share of car trips in both countries. Higher incomes and easier access to an automobile resulted in more car use. The HSM showed that faster car travel speeds compared to other modes were connected to more car use.

The empirical results also supported most of the hypotheses about differences in the strength of the coefficients of independent variables. Distance to a transit stop and population density had a weaker influence on car mode share in the U.S. compared to Germany. Income, gender, and access to an automobile, on the other hand, had a stronger influence on travel distance in Germany.

Heckman Selection Models (HSM) helped control for selection bias in the sample. While all statistical tests identified the presence of selection bias, its impact on the magnitude and sign of coefficients in the car travel distance OLS equation was small and limited to demographic variables. Among others, the HSM models identified access to a car, living close to transit, and relative speed as statistically significant variables to explain the choice to make a car trip on the travel day or not. These variables had a larger impact in Germany, hinting at a greater variability of transportation mode chosen there compared to the U.S.—where most trips are made by car even by households with few cars or close to transit.

Additionally, the bivariate analysis showed that similar people or similar spatial development patterns in both countries did not lead to identical travel behavior. For example, the highest income quartile in Germany traveled less by car than the lowest income quartile in the U.S. Germans living at low densities traveled less by car than Americans at high densities. The simulations confirmed these findings.

While transportation policies and spatial development patterns had a stronger influence on car travel distance in the U.S., they seemed to have had a stronger influence on mode choice. In the U.S., most trips were made by automobile, no matter if a household was in a dense area, close to transit or the speed of the car is relatively less competitive for a certain car trip or distance. However, car travel distance was found to be shorter in mixed land use and dense areas, as well as in households close to transit stops. In Germany, the difference in car travel distance was less pronounced, but the probability of choosing a mode other than the car was higher for households in mixed use and dense areas, close to transit, and if other modes were faster or at least competitive relative to the car.

Operating costs for automobiles were important in both countries. As cost per kilometer increased fewer kilometers are driven in a car. The simulations showed that increased cost for driving could considerably reduce daily car travel distance in the U.S. The next chapter will investigate explanatory factors for mode choice.

10 Modeling Mode Choice

This chapter focuses on explanatory factors for daily choice of transportation modes, including four choice categories: (1) automobile or light truck; (2) public transportation; (3) bicycle; or (4) walking. As in the other chapters, mode choice was regressed on transportation policies, spatial development patterns, socioeconomic and demographic variables, and a dummy variable representing culture. Additionally, trip purpose was included as an independent variable in this analysis. Public transportation for example is most economical for the work trip, as transit efficiency is maximized for commuting.

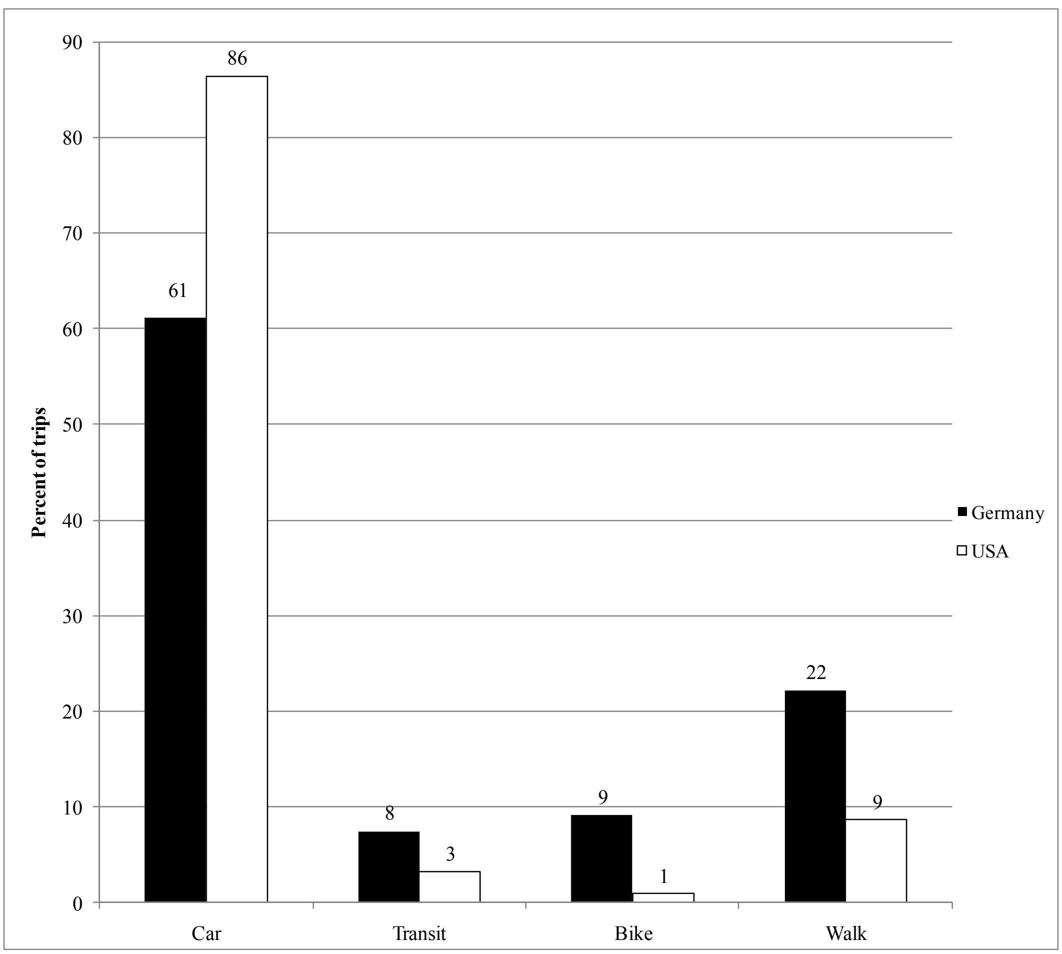
Modeling mode choice with four categories for the dependent variable is complex (Freese & Long, 2006). The task here was even more complicated by the fact that mode shares for public transportation and cycling were very small in the U.S. (less than three percent and one percent respectively). One solution would be to combine public transportation, cycling, and walking to one category and use a logistic regression with a dependent variable with two categories (automobile vs. non-automobile). Doing so would yield similar results to the HSM model in Chapter 9 and would hide important differences in mode choice between the car and walking, cycling, and transit use. Therefore, the dependent variable included four modes of transportation; even though this could potentially affect predictive accuracy. In contrast to Chapter 9, the units of analysis here were trips made by individuals during the travel day—excluding individuals who stayed at home.

10.1 Description of Univariate Distributions and Bivariate Relationships

10.1.1 The Dependent Variable

The percentage of trips made by car, transit, bicycle, and on foot in Germany and the U.S. were displayed in Exhibit 10.1. Germany's share of non-automobile travel was four times the U.S. share. Its bike share was almost ten times higher than the U.S. mode split for bikes, and transit-use accounted for four times more trips than the U.S. share. With 22 percent of all trips, walking had the second highest mode share behind the automobile in Germany; walking accounted for only nine percent of all trips in the U.S.

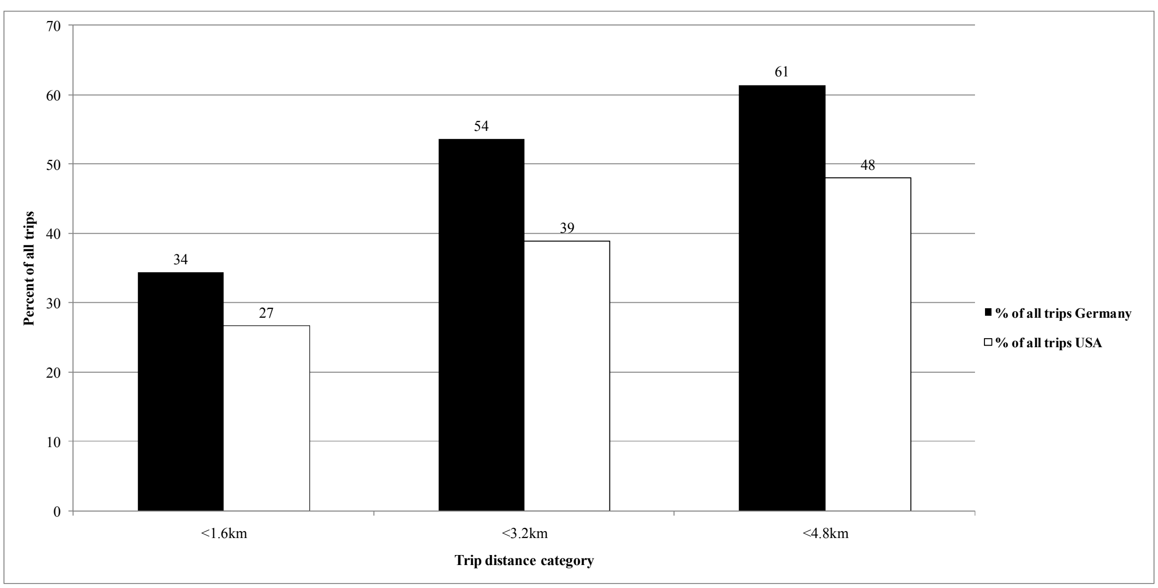
Exhibit 10.1 Percentage Share of Trips by Car, Transit, Bicycle, and Walking



(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

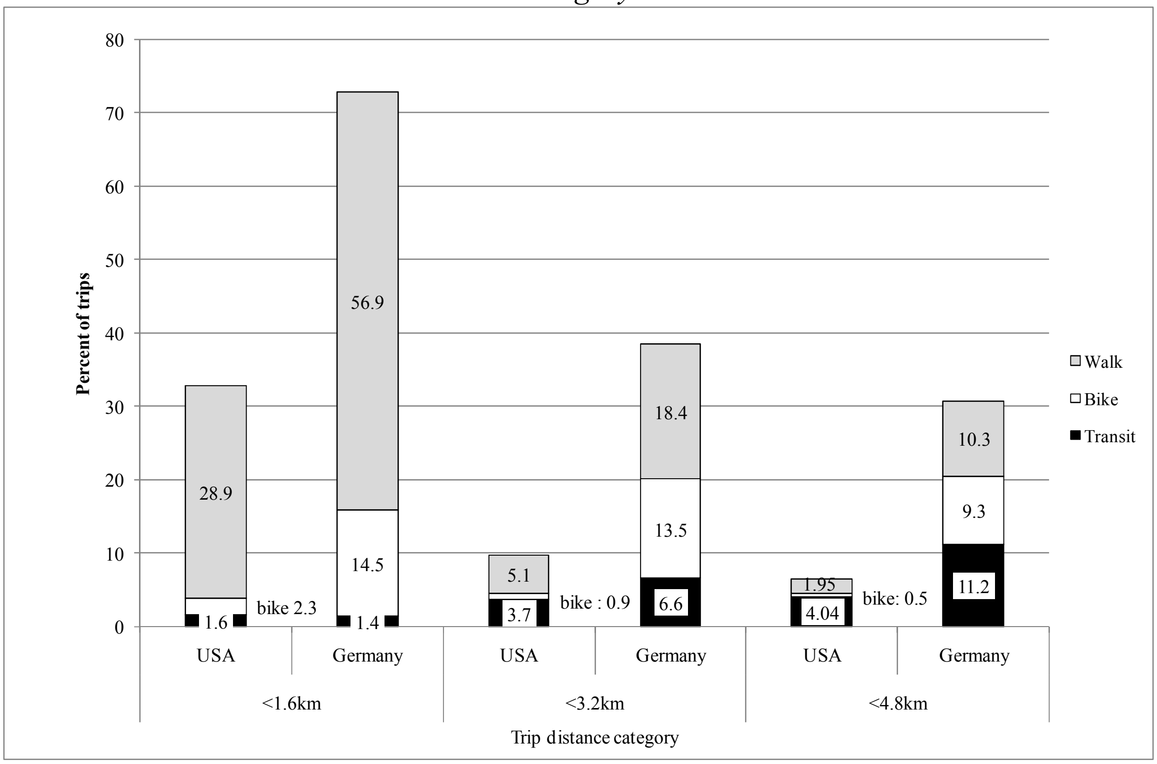
One might assume that the higher percentage of trips by automobile in the U.S. was due to longer average trip distances there compared to Germany. As expected, Exhibit 10.2 shows that short trips constituted a higher share of all trips in Germany compared to the U.S. In Germany 34 percent of all trips were shorter than 1.6km and 61 percent of trips were shorter than 4.8km while in the U.S. only 27 percent (<1.6km) and 48 percent (<4.8km) were shorter than 1.6 and 4.8 km respectively. Mode choice was dissimilar even for short trips, however. Exhibit 10.3 shows that in the U.S. the majority of short trips were made by car: 67 percent of trips shorter than 1.6km, 90 percent of trips shorter than 3.2km, and 93 percent of trips shorter than 4.8km. This compared to 27 percent (<1.6km), 61 percent (<3.2km), and 69 percent (<4.8km) mode share of car trips in Germany. Clearly, differences in trip distance alone could not fully explain dissimilarities in mode choice, as in the U.S. a considerably higher share of short trips were made by car.

Exhibit 10.2 Percentage Distribution of Trips by Trip-Distance Category



(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

Exhibit 10.3 Percentage Share of Trips by Transit, Bicycle, and on Foot by Trip-Distance Category



(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

10.1.2 Explanatory Variables

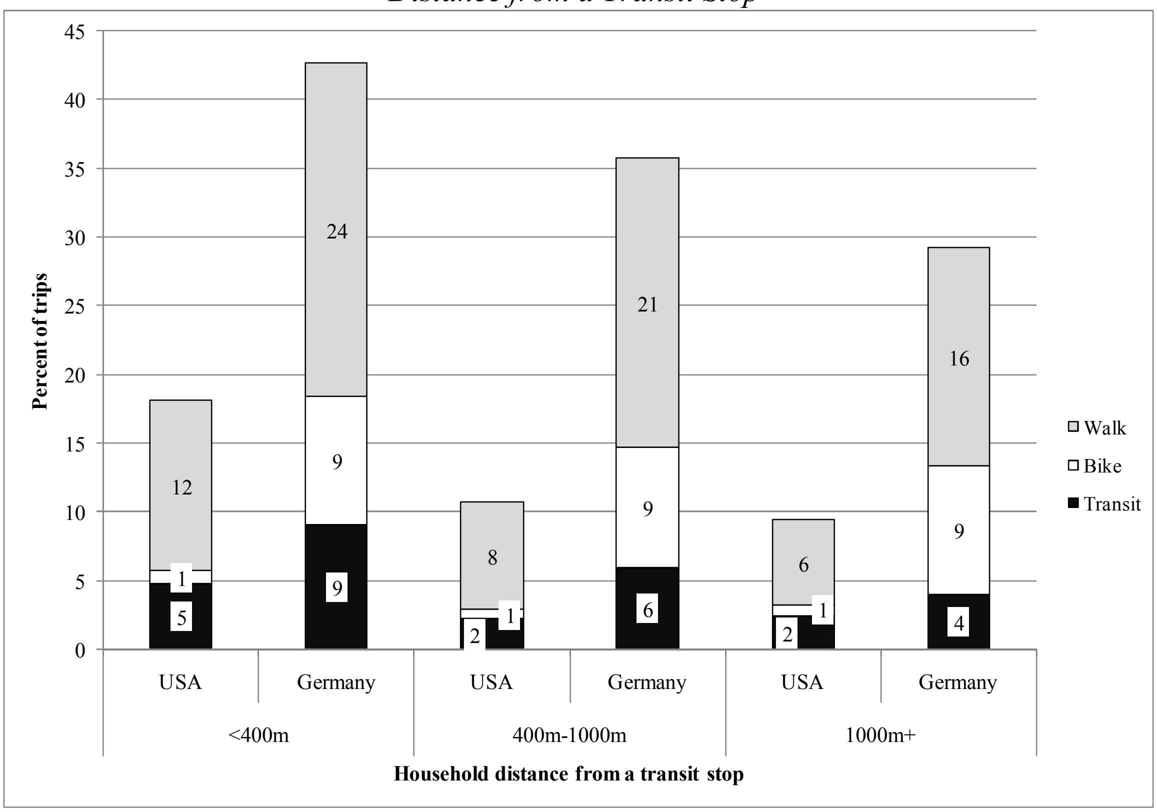
Univariate statistics for the independent variables were similar to Chapters 8 and 9 and were presented in the appendix. Problems with outliers and skewed distributions were detected and addressed in similar fashion as in the previous chapters.

10.1.2.1 Policy Variables

Distance to Public Transportation and Modal Split

Exhibit 10.4 shows that fewer trips in households living closer to public transportation were made by car and more on foot and by transit. In both countries, the share of trips by transit for households within 400m of a transit stop was twice as high as for households located more than 1000m from a transit stop. There was no relationship between bike use and household distance from a transit stop. Interestingly, trips in households who lived more than 1000m from a transit stop in Germany more likely made by bike, on foot, and by transit than trips in households living within 400m of a transit stop in the U.S.

Exhibit 10.4 Percentage Share of Trips by Transit, Bicycle, and on Foot by Household Distance from a Transit Stop



(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

Travel Speeds

Relative speeds of different modes of transportation can serve as an indicator for the attractiveness and competitiveness of the transportation modes. In 2001/2002, the average car trip speed (door to door) in the U.S. was 41km/h, compared to 33km/h in Germany (based on data from NHTS and MiD). Reported average transit speeds (including wait time) were about 18km/h in both countries. Average reported bike trip speeds were 11km/h in Germany and 10km/h in the U.S. Reported speeds of walking trips were 4.5km/h in Germany and 5km/h in the U.S. (about 20 minutes per mile). Faster average car speeds relative to other modes made the automobile more competitive in the U.S.

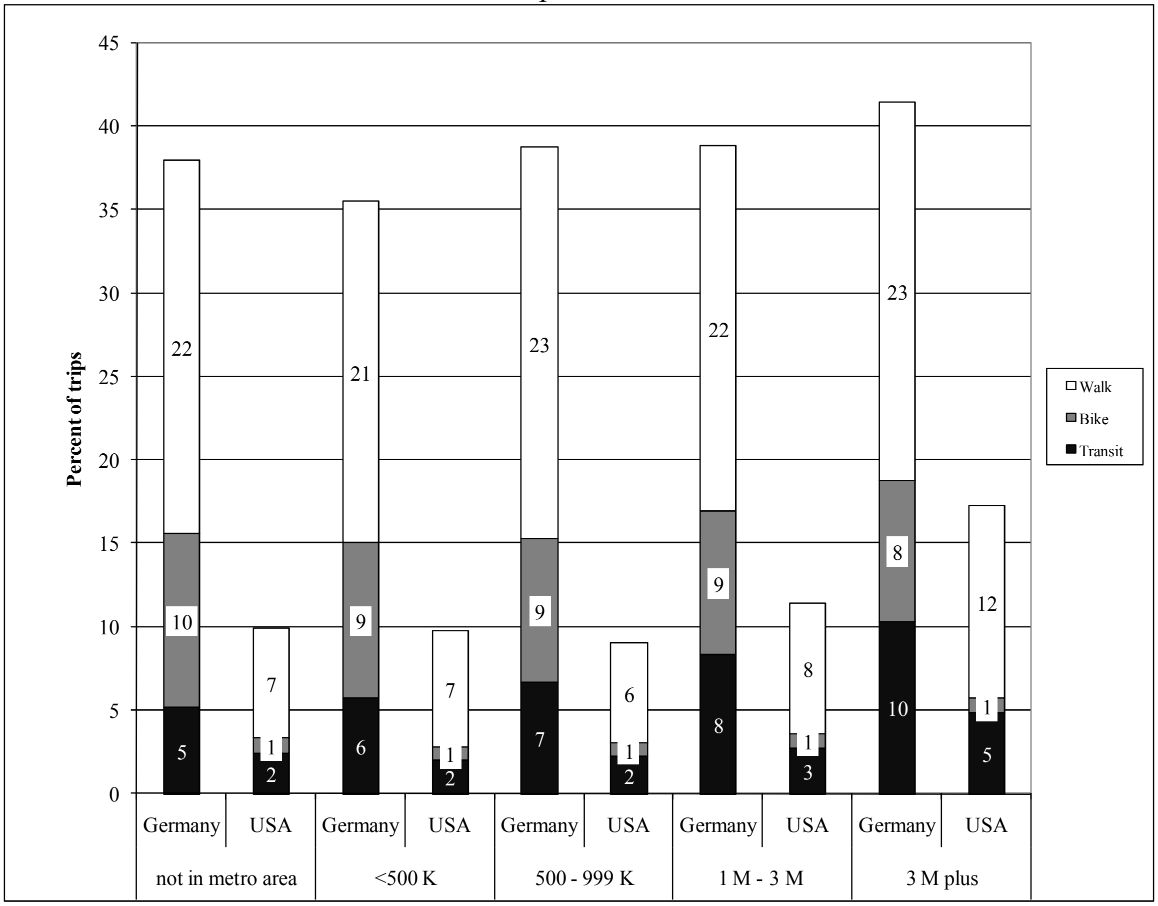
As shown in Chapter 9 travel speeds for most modes of transportation varied by trip distance. Short trips were generally slower than longer trips when considering the time per kilometer. In both countries and for all trip-distance categories, average speeds for the automobile were faster than trips by any other mode of transportation. Travel speed data were mode specific and required a special modeling strategy. Therefore this variable was only used in the conditional logit model in the second analysis. Details will be presented later in this chapter.

10.1.2.2 Spatial Development Patterns

Metropolitan Area Size

In both countries, there were higher levels of transit use and a lower share of car trips in larger metropolitan areas. In Germany, bicycling declined slightly as MSA size increased. Walking increased with MSA size in the U.S. In Germany, the share of trips by bike, transit, and on foot outside of metropolitan areas was higher than for trips in the largest MSA category in the U.S. Overall, there was not much variability in mode split for metropolitan area size. Metropolitan area size was a crude measure, which masked a lot of variability within a larger area. Neighborhoods and settlements within one metropolitan area can be very different. These differences were not captured by this crude variable. Additionally, metropolitan area size was highly correlated with population density, mix of land uses, and transit access. As for the other two analyses, metropolitan area size category was omitted from the multivariate analysis.

Exhibit 10.5 Percentage Share of Trips by Transit, Bicycle, and on Foot by Metropolitan area Population Size

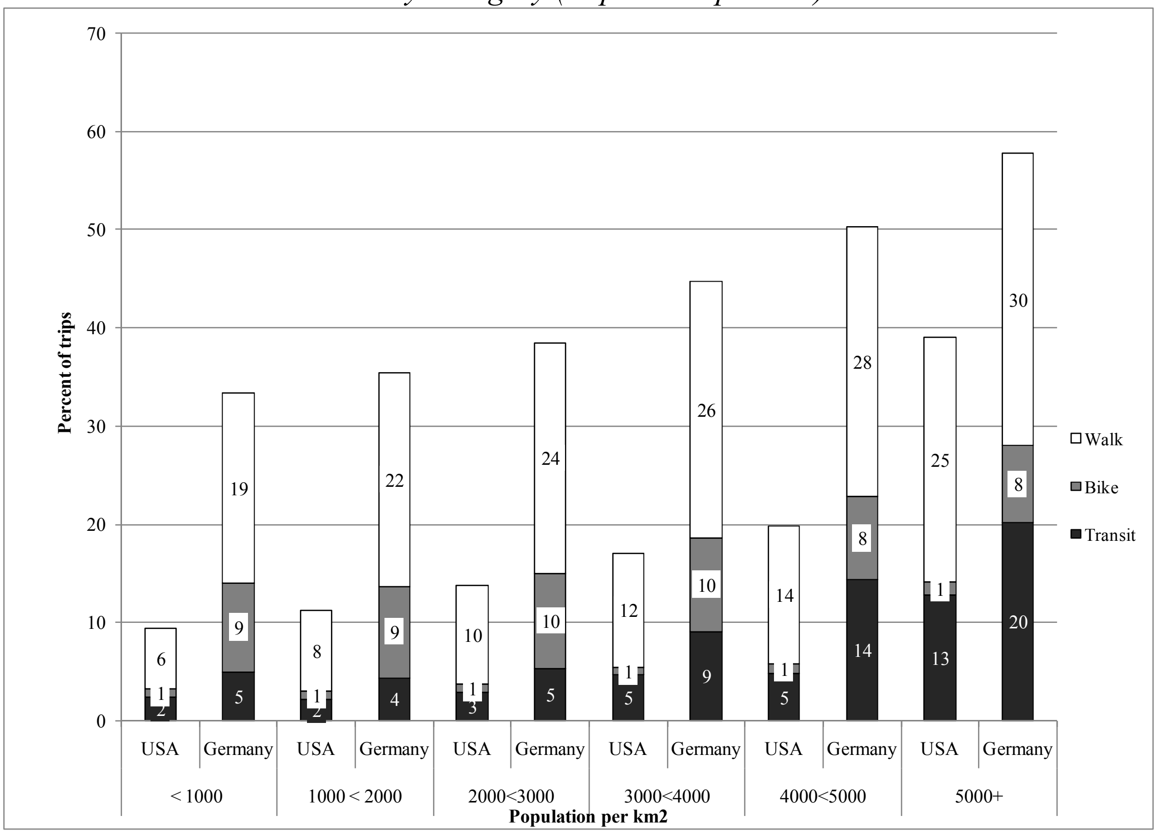


(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

Population Density

Higher population densities were associated with less car use and more walking and transit use in both countries. The share of trips by bike declined slightly for the highest density categories in Germany, which could be caused by increased transit use, as public transport—which is most economical at high population densities—was found to compete with the bicycle in some European cities (Schwanen, 2002). In Germany, the share of trips by car in the lowest density category was lower than the share of trips in the highest density category in the U.S. Similarly, the share of transit and walking in the second highest density category in the U.S. compared to the lowest density category in Germany.

Exhibit 10.6 Percentage Share of Trips by Transit, Bicycle, and on Foot by Population Density Category (Population per km^2)

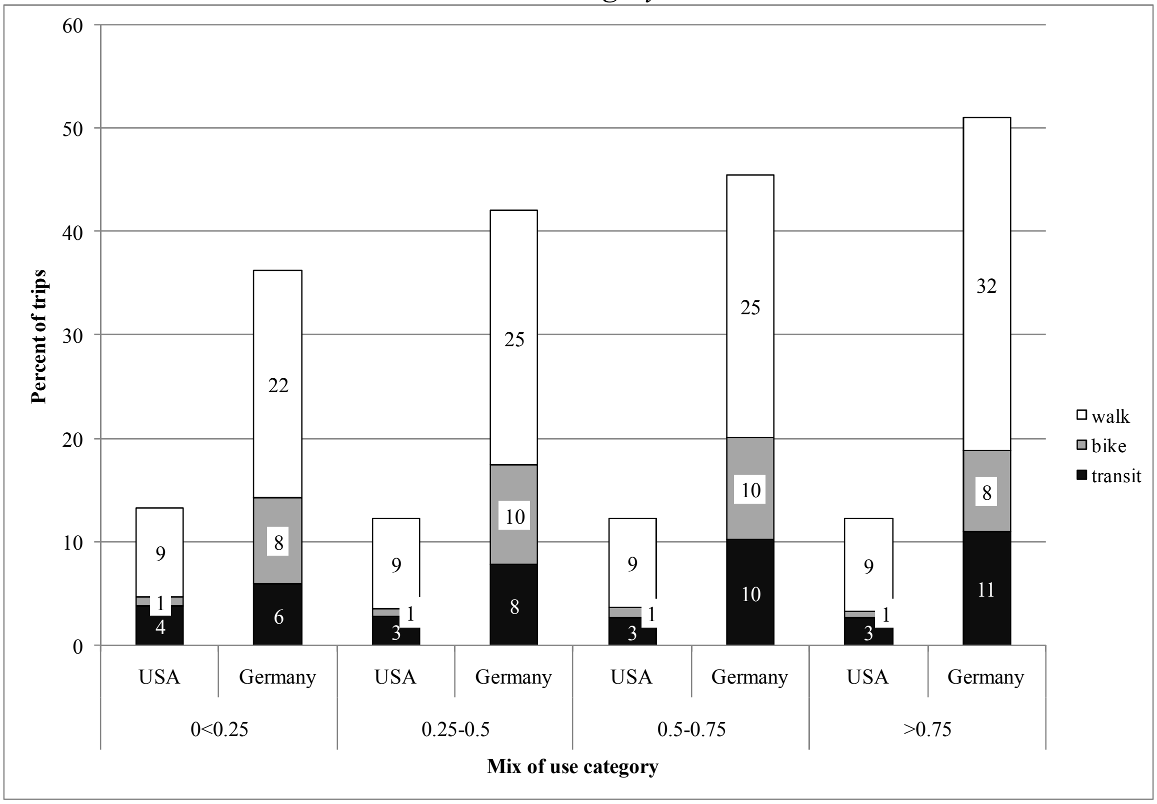


(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

Mix of Land Uses and Mode Choice

Exhibit 10.7 shows that in Germany a greater mix of land uses was associated with less car travel and more walking, cycling, and transit use. For the U.S., the mix use variable did not seem to have any influence on modal split, even though greater mix of land uses resulted in shorter trips in both countries, which should have been associated with more non-automobile transportation.

Exhibit 10.7 Percentage Share of Trips by Transit, Bicycle, and on Foot by Mix of Land-Use Category



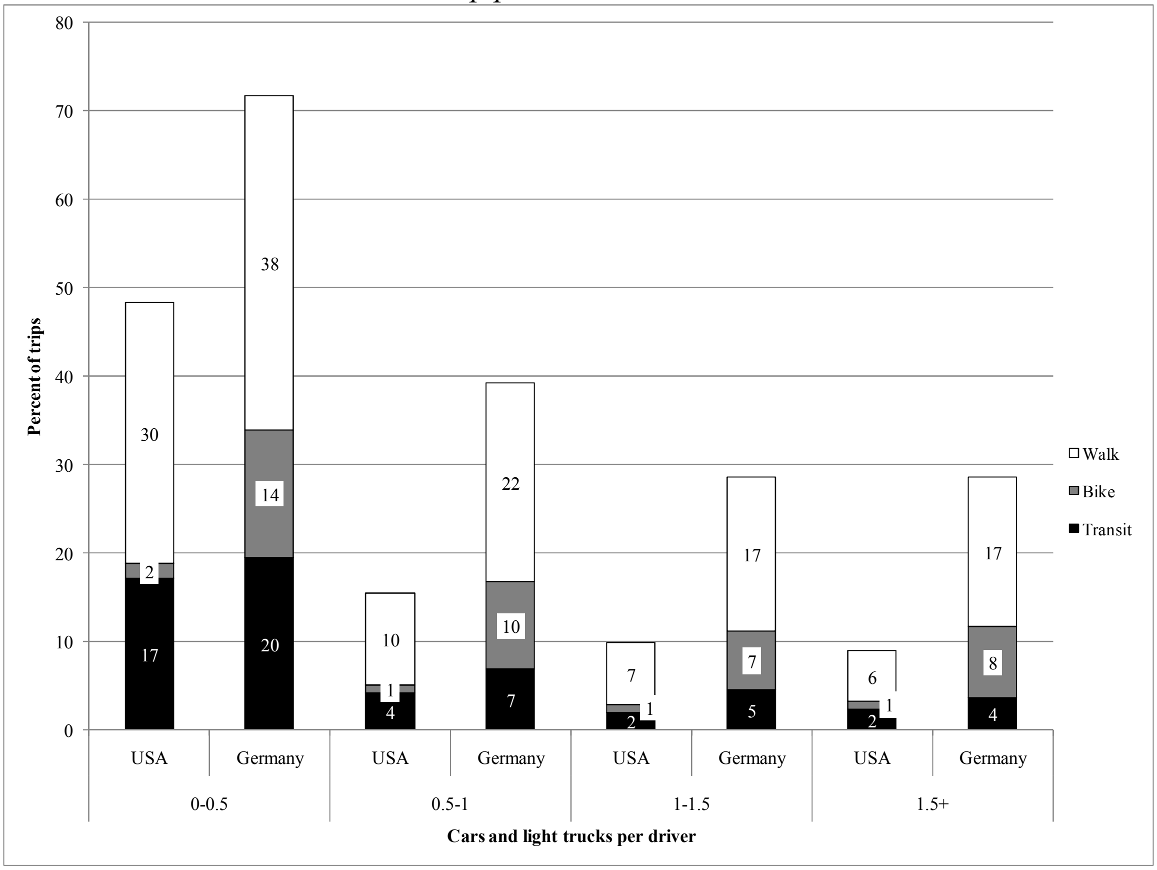
(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

10.1.2.3 <u>Socioeconomic and Demographic Variables</u>

Cars per Household and Mode Choice

In both countries, a higher share of trips was made by car in households that owned more cars. The percentage shares of transit, walk, and bicycle trips declined with increasing household car ownership in each country. In both countries, the largest variability in mode share existed between households with 0 to 0.5 cars per household member at driving age and the next highest car ownership category. Still, in the U.S. the share of trips by car in households with 0 to 0.5 cars was over 50 percent, most likely due to the lack of alternative means of transportation.

Exhibit 10.8 Percentage Share of Trips by Transit, Bicycle, and on Foot by Automobile Ownership per Household Member

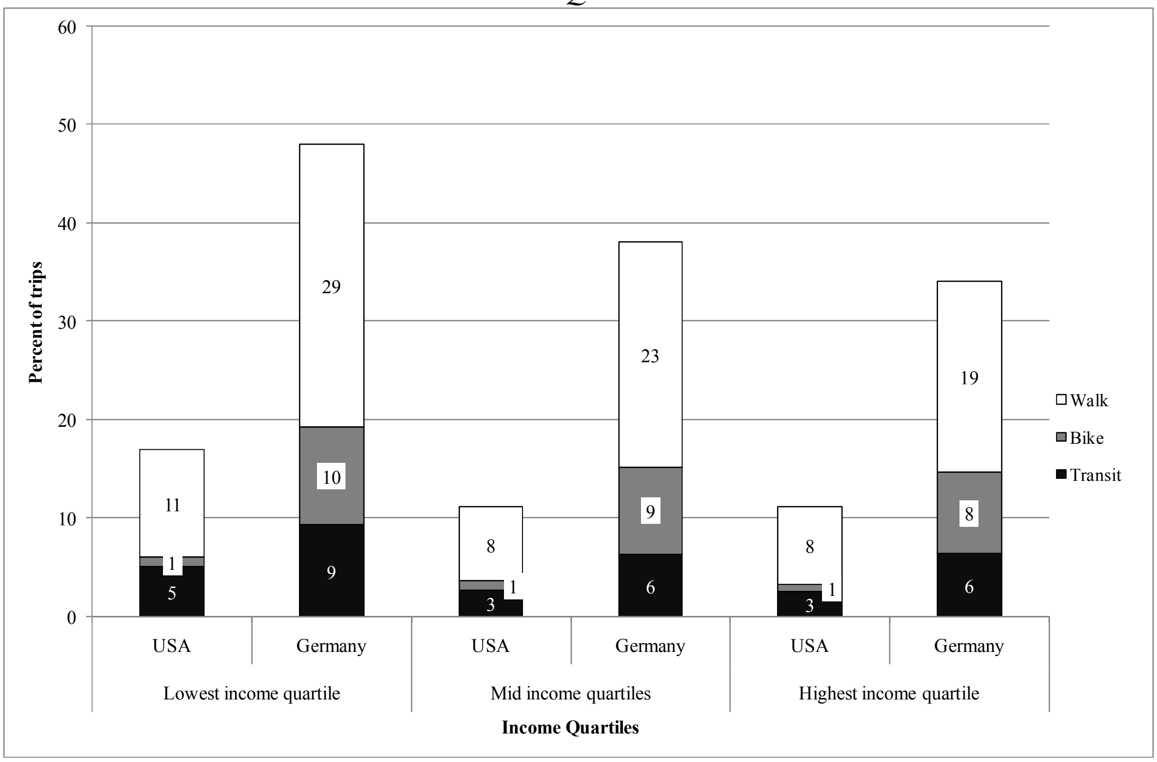


(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

Household Income and Mode Choice

In both countries, higher household incomes were related to more car travel and fewer trips by transit, walking, and bicycle. The U.S. distribution was more homogenous than for Germany. In the U.S. the share of trips by car for the lowest income quartile was six percent lower than the share of trips for the highest income quartile (82 percent vs. 88 percent), while in Germany this difference was twice as large at 12 percent (54 percent vs. 68 percent respectively). In each income quartile the share of trips on foot, by bike, and public transportation in Germany was three times higher than in the U.S. The share of trips by car for the richest German quartile was lower than for the poorest American quartile. The mode share of transit, walk, and bike for wealthy Germans was two to eight times higher than for poorer Americans.

Exhibit 10.9 Percentage Share of Trips by Transit, Bicycle, and on Foot by Household Income Quartiles



(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

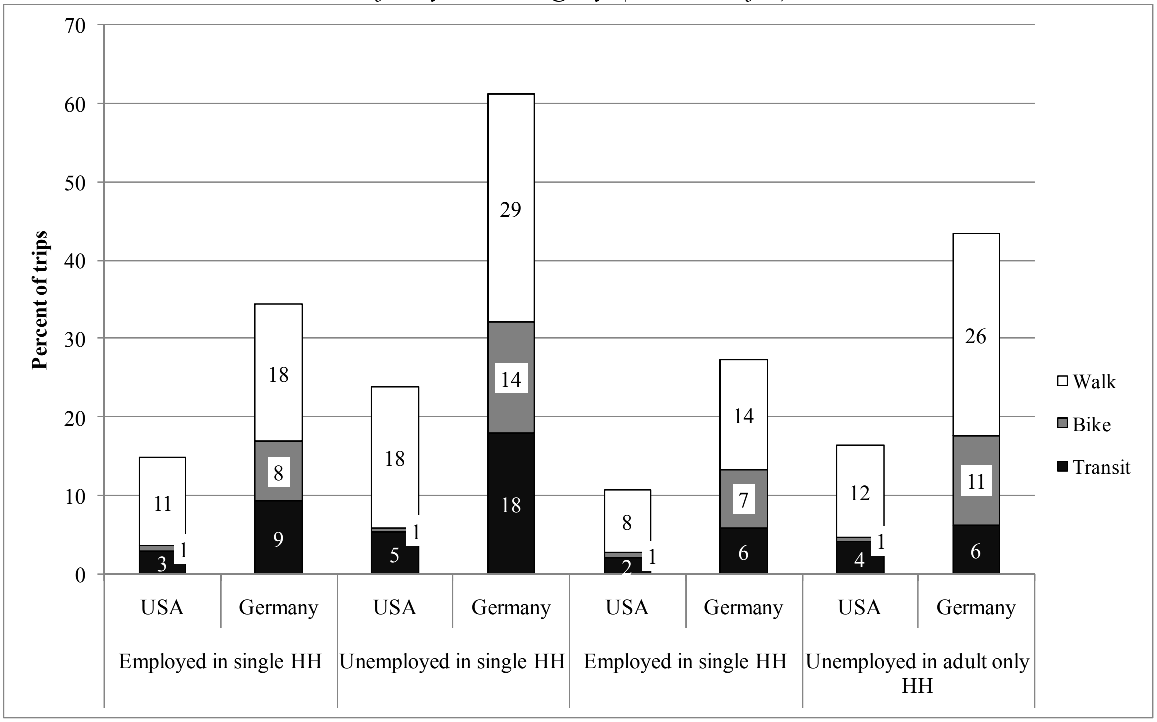
Mode Choice by Driver's License, Gender, and Age

Not surprisingly the share of trips by car in either country was higher for individuals with a driver's license: 92 percent of trips for individuals with a license and 62 percent of trips for individuals without a license in the U.S. compared to 68 percent and 37 percent in Germany respectively. In the U.S. the share of trips by car was 87 percent for men and women. There was a gender gap in Germany however: 65 percent of trips were by car for men compared to only 57 percent for women. In Germany, trips made by women were more likely made by public transportation than trips made by men. In Germany, the share of trips by bike was the same for men and women (9 percent). In contrast to Germany, in the U.S., the share of trips by bike for men was twice of that for women (1.2 percent vs. 0.6 percent). Walk and transit shares were about the same for men and women in the U.S.

Household Life Cycle, Employment and Mode Choice

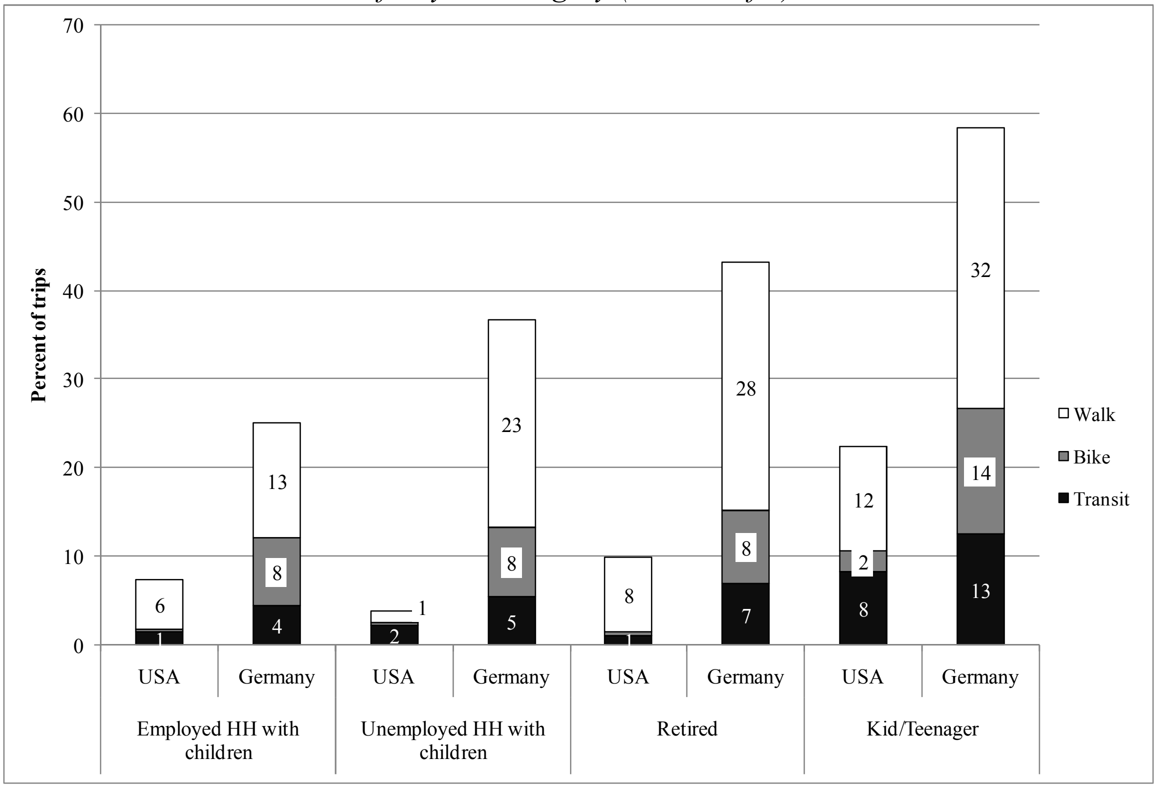
Exhibits 10.10 and 10.11 show that, for every household life cycle category, the share of trips by car was lower for unemployed than employed individuals. In both countries, the share of car trips was the highest for employed adults in households with children. The share of trips by car was 90 percent in retired households in the U.S. In Germany, the share of trips by bike (8 percent), walk (28 percent), and transit (7 percent) was 42 percent. In the U.S. the mode share of car use for children and teenagers under driving age was 77 percent, compared to 42 percent in Germany. The percentage shares of trips on foot and by transit were three and seven times higher for children in Germany than in the U.S.

Exhibit 10.10 Percentage Share of Trips by Transit, Bicycle, and on Foot by Household Life Cycle Category (Table 1 of 2)



(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

Exhibit 10.11 Percentage Share of Trips by Transit, Bicycle, and on Foot by Household Life Cycle Category (Table 2 of 2)

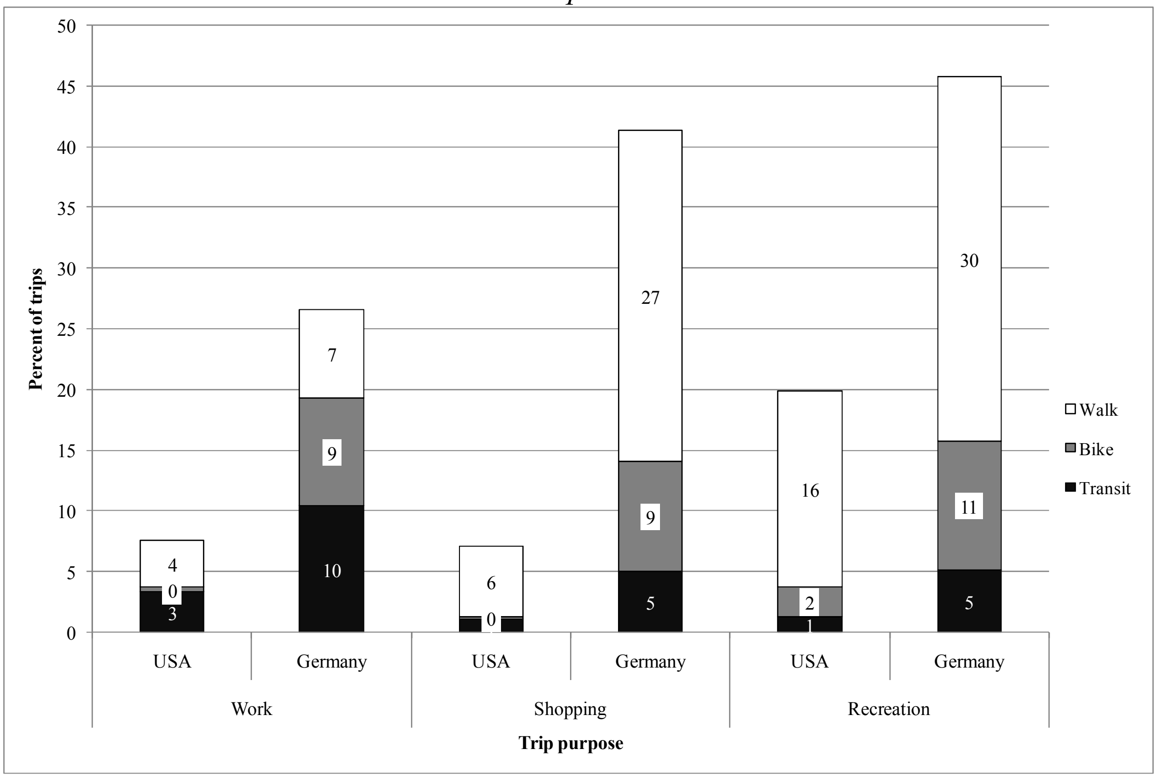


(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

10.1.2.4 *<u>Mode Choice by Trip Purpose</u>*

Trip purpose could also have an important impact on mode choice. Transit service is well suited for commuting—as a large number of employees can be efficiently carried to employment centers in downtown. Additionally, most transit systems provide the highest frequency of transit service during morning and afternoon peak travel hours. Shopping trips are most likely made by automobile, as groceries and other purchases have to be carried home. For both, shopping and work trips it was assumed that individuals choose the mode, which minimized their travel time. Recreational trips did not necessarily fulfill this premise, however. Exhibit 10.12 shows mode splits for three trip purposes.

Exhibit 10.12 Percentage Share of Trips by Transit, Bicycle, and on Foot by Trip Purpose



(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

<u>Proxy for other National Differences U.S. – Germany Dummy Variables</u>

This variable simply identified German and American respondents (1=Germany, 0=US). Mode shares by country were discussed above already. About 59 percent of trips in this sample were from the U.S.

10.1.3 Bivariate Correlations

Table 10.1 presents bivariate correlations between all variables included in the multivariate analysis. All bivariate correlations were statistically significant, which was not surprising given the sample size. As in the other two analysis chapters, correlations higher than the absolute value of 0.3 were found between car ownership, density, transit access, and the Germany dummy variable. These correlations suggested that households in denser areas had better transit access and owned on average fewer automobiles. Furthermore, Germans generally lived in denser settlements and owned fewer cars than Americans.

Table 10.1 Bivariate Correlations for Independent and Dependent Variables

	Transit Access <400	Transit Access 400-1000m	Density	Mix	Car Access	Income	Male/ female	With job in single HH	W/o job in single HH	With job in couple HH	W/o job in couple HH	W/o job in HH with child	Retired HH	Child/ teenager	Work Trip	Shopping Trip	Germany / USA
Transit Access <400	1.00																
Transit Access 400-1000m	*-0.44*	1.00															
Density	*0.42*	0.14	1.00														
Mix	0.07	-0.01	0.06	1.00													
Car Access	-0.23	-0.10	*-0.35*	-0.05	1.00												
Income	-0.08	0.00	-0.10	-0.03	0.27	1.00											
Male/ female	-0.01	0.00	0.00	0.00	0.04	0.04	1.00										
With job in single HH	0.03	-0.02	0.03	0.05	0.10	-0.13	0.01	1.00									
W/o job in single HH	0.03	-0.01	0.04	0.02	-0.05	-0.12	-0.01	-0.02	1.00								
With job in couple HH	-0.03	-0.04	-0.07	0.00	0.08	0.15	0.05	-0.10	-0.04	1.00							
W/o job in couple HH	0.04	0.03	0.08	0.01	-0.09	-0.04	-0.05	-0.05	-0.02	-0.10	1.00						
W/o job in HH with child	0.01	0.02	0.02	-0.02	-0.05	-0.01	-0.14	-0.07	-0.03	-0.13	-0.07	1.00					
Retired HH	0.02	0.00	0.03	0.03	-0.13	-0.20	0.00	-0.13	-0.05	-0.25	-0.13	-0.16	1.00				
Child/ teenager	0.04	0.07	0.08	-0.01	-0.04	-0.01	0.01	-0.08	-0.03	-0.16	-0.08	-0.10	-0.20	1.00			
Work Trip	-0.04	-0.03	-0.06	-0.01	0.09	0.09	0.08	0.08	-0.04	0.17	-0.11	-0.13	-0.16	-0.16	1.00		
Shopping Trip	0.02	0.00	0.02	0.01	-0.05	-0.05	-0.06	-0.02	0.01	-0.03	0.05	0.05	0.10	-0.10	-0.29	1.00	
Germany / USA	0.23	0.28	*0.49*	0.04	*-0.43*	-0.20	0.00	-0.06	0.02	-0.15	0.13	0.04	0.04	0.24	-0.10	0.02	1.00
if not inicated differently: all correlations significant at 0.01 level (two tailed)																	

(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

10.1.4 Findings from Bivariate Analysis

Almost all variables had the expected relationships with the dependent variable. The only exception was the mix of land uses, which did not have an influence on mode choice in the U.S. in this particular sample. For all variables, the U.S. displayed a greater share of trips made by car than Germany throughout the range of the distribution of the independent variables.

For some variables the largest share of trips by car in Germany was even less than the least share of trips made by car found for the U.S. For example, the share of car trips in the lowest income quartile in the U.S. was higher than that in the highest income quartile in Germany. Similarly, mode shares of walk, bike, and transit trips in the highest income quartile in Germany were two to nine times higher than those in the lowest income quartile in the U.S. The expected theoretical relationship of more car use with increasing incomes held true within each country individually; but differences between the countries could not solely be explained by differences in income. Theory would lead us to expect that everything else equal, the mode share of trips by car should be higher for wealthier Germans than poorer Americans; and that the mode share would be comparable for similarly wealthy individuals in either country. The bivariate analysis did not confirm this expectation, leading to the conclusion that other contextual factors may help explain these differences.

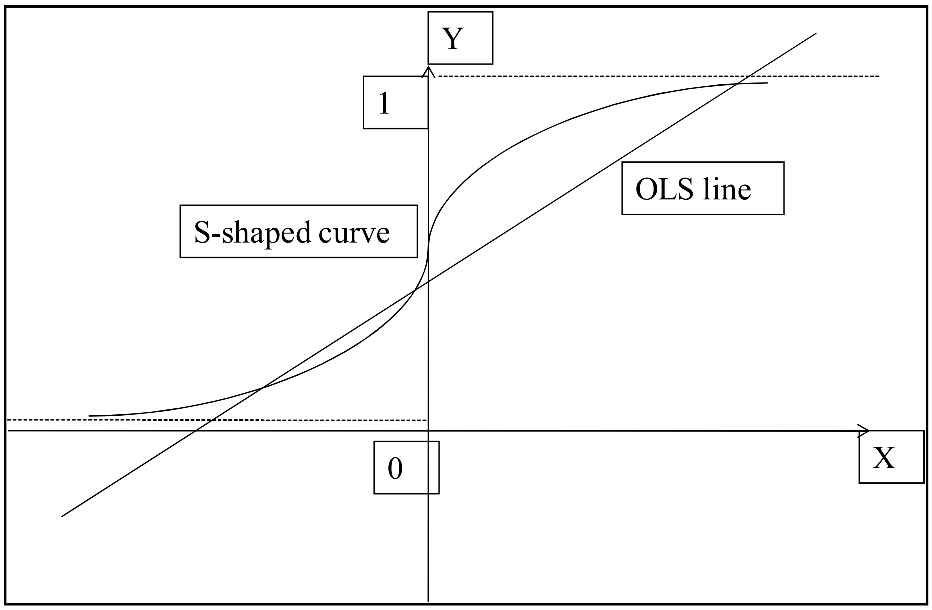
Similarly, the share of trips by car for households living at population densities of over 5,000 people per km^2 in the U.S. was higher than that for Germans households at population densities of less than 1,000 people per km^2. This was contrary to expectations, as theory and past empirical observations would suggest that similar people in similar spatial settings should display similar travel behavior, everything else equal. If this held true, one would expect a higher share of trips by car in German households living at lower population densities than their American counterparts. The theory of less car use with increasing population density holds true again for both countries, but could not explain differences in mode split *between* the countries. The multivariate regression analysis in the next section sheds more light on difference in travel controlling for other explanatory factors.

10.2 Multivariate Analysis: Multinomial Logistic Regression for Mode Choice

Daily transportation mode choices could not be modeled using linear regression for conceptual and statistical reasons (Long, 1997). First, a trip can only be made by one mode of transportation at a time—therefore a continuous dependent variable as for OLS is not appropriate. Second, probabilities for choosing a mode of transportation can only range from zero to one. Linear regression models would predict results outside of this range. Third, a linear model would result in inefficient estimators, because errors for discrete data are not homoskedastic, but rather multinomial or binomially distributed. Fourth, a linear model assumes a constant marginal effect of independent on dependent variables. In the case of discrete choice the marginal effects are diminishing towards either end of the probability function.

In order to solve these problems, researchers developed discrete choice models. These models overcome the limitations of linear models by either (1) transforming the discrete choice on the left hand side of the equation (e.g. into a logit (or log of odds)), or by (2) exponentiating the utility function on the right hand side of the equation in order to restrict it to the range of zero to one. Instead of a straight line, as in OLS, these models estimate a symmetric s-shaped curve (see Exhibit 10.13). It is easy to see that compared to the OLS line this curve: (1) ranges from zero to one for all values of X and (2) accounts for the decreasing marginal effect of X on Y towards both ends of the distribution. For values of X below the intersection of the s-shaped curve and Y the predicted outcome is zero, otherwise the prediction is one.

Exhibit 10.13 OLS Regression Line and S-Shaped Curve



Modeling travel demand using discrete choice methods emerged in the 1950s. The 1970s saw major changes in the field and the appearance of models including more than two modes (Bates, 2000). Models have become increasingly complex and advanced since then (Long & Freese, 2006).

Generally, mode choice models assume that each individual chooses the mode of transportation that maximizes his or her individual utility. If there are *J* transportation alternatives, an individual *i* would choose mode *j* if the utility for mode *j* is larger than the utility for all other modes *m*.

[Equation (1) $U_{ij} > U_{im,\, for}$ *all* $m \neq j$*]*

For example an individual would choose the car if the utility derived from an automobile trip is larger than the utility of a walk, bike or transit trip. Individual utility was assumed to consist of a measurable deterministic component *V* and a non-measurable random error component *e*.

[Equation (2): $U_{ij} = V_{ij} + e_{ij}$*]*

The deterministic component *V* could include (a) characteristics of the trip decision maker and (b) attributes of the transportation modes. Characteristics of the decision maker were for example socioeconomic and demographic variables or information describing spatial development patterns. Transportation mode specific variables were, for example, travel time or cost for each transportation mode available to the trip maker.

Depending on the number of categories and assumptions about the distribution of the error *e*, different models could be estimated. The assumption of an independent and identical type I extreme (Gumbel) distribution would give rise to the multinomial logit model, distinguishing between more than two modes of transportation (Koppelman and Sethi 2000).

The choice of independent variables also determined the type of model to be estimated. (1) If only variables about the trip maker were included, then the adequate model would be a multinomial logit model. (2) Conditional logit models would be estimated if variables solely described transportation alternatives. (3) A combination of individual and transportation mode variables would give rise to a mixed model or generalized logit model. The models are given below:

[Equation (3): Multinomial Logit Model *with* $V_{ij}=\Sigma x_{ik}\beta_{kj}$*]*

[Equation (4): Conditional Logit Model with $V_{ij}=\Sigma x_{kij}\beta_k$*]*

[Equation (5): Mixed Logit Model with $V_{ij}=\Sigma(x_{ik}\beta_{ik+} Z_{ik}\gamma_k)$]

[With V=utility; X_k*=person specific independent variable;* Z_k*=mode specific independent variable;* β_k*=slope of person specific independent variable k;* γ_k*=slope of mode specific independent variable* k_i*=individual; j=mode of transport]*

Multinomial models would estimate different slopes (βs) for each independent variable for each category of the dependent variable. For example, car ownership could have different effects on transit use, walking and cycling—therefore three different slopes (βs) would be estimated. In its simplest form the conditional logit estimates the same βs for all categories of the choice alternatives.[138] Mixed logit models combine individual specific with choice specific variables and estimates slopes for both.

Most variables available for this analysis were for the trip maker; therefore the first set of models was a multinomial logit model. In this case the probability *P* that individual *i* chose mode *j* was:

[Equation (6): $P_{ij}=(e^{Vij})/(\Sigma^{J-1}e^{Vij}))$ *with* $V_{ij}=\Sigma x_{ik}\beta_{kj}$*]*

e stands for the exponential function (Euler's Number) and *V* is the deterministic part of the utility function. *J* represents the number of mode alternatives. In simple words the probability of choosing a mode corresponds to the exponential function of the utility of this particular mode divided by the sum of the exponential functions of the utilities of all modes (J-1).

This model assumed independence and equal variance. This assumption—referred to as independence of irrelevant alternatives or IIA—states that the probability of

[138] Interaction effects can be estimated to account for alternative specific differences.

choosing one mode of transportation over another is not influenced by the presence of a third mode (Ben-Akiva & Lerman, 1985; Koppelman & Sethi, 2000). Even though they are not very reliable, statistical tests could be carried out to see if this assumption holds true (Freese & Long, 2006).

The model above only included variables about the trip makers and their surroundings. It did not capture any *transportation mode specific* variables. The only such variable available in the datasets was travel speed. In a second step, a conditional logit model was estimated using trip speeds as a mode specific variable. In the case of the conditional logit model the probability P that individual i chose mode j depended on the individual utility that takes individual X and mode specific Z variables into account:

[*Equation (7):* $P_{ij}=(e^{V_{ij}})/(\Sigma^{J-1}\ e^{V_{ij}})$ *with* $V_{ij}=\Sigma(x_{ik}\beta_{ik+}\ Z_{ijk}\gamma_k)$]

(definitions as above)

10.2.1 Multinomial Logit Model (MNLM)

As for Chapters 8 and 9, the first set of models was based on a pooled sample. Results of this MNLM were presented in Table 10.2. Multinomial models were more complicated to interpret than binary choice models, choosing between two alternatives (Long & Freese, 2006). In order to interpret these models, one category of the dependent variable had to serve as a base case or reference category. Generally, the alternative with the highest mode share was used as reference category; in this case it was the automobile. The coefficients in Table 10.2 reported the effect of each independent variable on each category of the dependent variable (transit, bike, and walk) *relative* to the base category. For example, coefficients in the third column compared the choice of transit relative to the automobile. Columns four and five compared bicycling or walking to car use respectively.

Table 10.2 Dependent Variable: Mode Choice

		Mode of Transport		
		Transit	**Bike**	**Walk**
	Constant	**-3.178**	**-4.011**	**-1.755**
		(46.16)**	(47.86)**	(40.72)**
	Germany(1/0)	**0.938**	**2.639**	**1.032**
		(31.95)**	(55.97)**	(50.26)**
Policy	Transit access <400m	**0.04**	**-0.009**	**0.324**
		-1.21	(0.21)	(14.28)**
	Transit access 400-1000m	**-0.206**	**-0.063**	**0.115**
		(5.33)**	(1.39)	(4.55)**
Spatial development patterns	Population density	**0.27**	**-0.003**	**0.122**
		(31.67)**	(0.24)	(19.76)**
	Mix of use	**0.37**	**0.395**	**0.288**
		(5.73)**	(4.79)**	(6.93)**
Trip Purpose	Work trip	**0.495**	**-0.122**	**-1.214**
		(15.77)**	(3.42)**	(45.48)**
	Shopping trip	**-0.939**	**-0.361**	**-0.554**
		(27.12)**	(12.28)**	(32.65)**
Socioeconomic and demographic variables	Car access/availability	**-1.493**	**-1.263**	**-0.887**
		(28.79)**	(23.93)**	(28.82)**
	Household income	**-0.002**	**0.001**	**-0.002**
		(4.26)**	(1.25)	(5.59)**
	Sex (Male=1)	**-0.242**	**0.116**	**-0.147**
		(9.59)**	(4.13)**	(9.12)**
	Single HH with job	**0.532**	**0.388**	**0.467**
		(7.50)**	(4.22)**	(9.94)**
	Single HH without job	**1.246**	**0.983**	**0.591**
		(10.79)**	(6.86)**	(6.82)**
	Couple HH with job	**-0.028**	**-0.043**	**0.193**
		(0.52)	(0.72)	(6.40)**
	Couple HH without job	**0.601**	**0.514**	**0.288**
		(9.06)**	(8.34)**	(7.64)**
	HH, children without job	**0.547**	**0.206**	**0.068**
		(8.87)**	(3.20)**	(1.95)
	Retired HH	**0.274**	**0.177**	**0.286**
		(6.44)**	(4.10)**	(12.20)**
	Younger than 16/18	**2.361**	**1.532**	**0.91**
		(63.79)**	(37.99)**	(37.48)**
Model Fit	Observations	343974		
	McFadden R-Square	16.4		
	Cox-Snell R-Square	22.9		
	Nagelkerke R Square	28.8		
	Log Likelihood Intercept	-271541.78		
	Log Likelihood Full	-226868.729		
	Probability> Chi Square	0.000		
Base outcome= car				
Absolute value of z statistics in parentheses				
* significant at 5%; ** significant at 1%				

(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

The goodness of model fit can be accessed through Pseudo-R^2 statistics and Likelihood Ratio (LR) tests. Pseudo-R^2s for the model ranged from 16.4 percent (McFadden's R^2) to 28.8 percent (Nagelkerke's R^2). These different Pseudo-R^2 statistics try to approximate the well known measure from OLS. Alternative ways to approximate R^2 led to different outcomes, however. R^2 for individual groups of independent variables were: 3.4 to 6.5 percent for policy variables, 4.4 to 8.2 percent for land use variables, 10.6 to 17.5 percent for socioeconomic and demographic variables, and 2.0 to 3.9 percent for the trip purpose variables.

According to the Likelihood Ratio (LR) test the H_0 that all βs were equal to zero could be rejected for the final model. When groups of independent variables were entered sequentially into the model, LR tests could compare the full model to reduced model structures. In all cases the H_0 could be rejected on the 99 percent confidence level; so all groups of independent variables contributed significantly to the model.

As indicated above the MNLM assumed independence of irrelevant alternatives (IIA), which implied that the probability of choosing one mode over the other is not influenced by a third mode that was not part of this specific decision. For example the choice to use the bike over the car did not depend on the potential choice of walking. Two tests for IIA exist, but the Hausmann and Small-Hisao tests, often produce contradictory results and are not very reliable (Long & Freese, 2006). For this sample, the Hausmann test concluded that the model was a good fit for all contrasts (bike vs. car, walk vs. car, transit vs. car), and the Small-Hsiao estimated that the model was a good fit for two out of three contrasts. For these situations McFadden (1973 cited in Long & Freese, 2006) suggested that the IIA assumption holds if the dependent variables can "*plausibly be assumed to be distinct and weighted independently in the eyes of the decision maker.*" Amemiya (1981 as cited in Long & Freese, 2006) suggests *"that MNLM works well when the alternatives are dissimilar"*. It was assumed here that car, transit, walking, and automobile were distinct modes that were dissimilar. A Wald Test for dissimilarity of contrasts confirmed this.

This model predicted the mode share in Germany well. Car and transit trips in Germany were predicted lower than they actually had been (59 percent predicted vs. 61 percent for the car and six percent predicted vs. 7.5 percent). Walk and bike trips were estimated to be slightly higher than they actually had been (24 percent vs. 22 percent for walking and 11 percent vs. nine percent for cycling). For the U.S. the prediction was slightly less accurate, which was likely related to the large percentage share of car use and the small percentages of transit use and cycling. For the U.S., car use was predicted to be 3.5 percent higher than the actual mode share at 91.5 percent and walking, cycling, and transit use were predicted to be lower than they actually had been (6.5 percent vs. 8.5 percent for walking, 0.7 percent vs. 0.9 percent for cycling, and 1.4 vs. three percent for transit use).

The interpretation of coefficients of MNLM was not as straight forward as for linear regression models. For example, exponentiation of the coefficient for Germany for walking ($e^{1.032}$), cycling ($e^{2.639}$), and transit use ($e^{0.938}$) reveals that compared to trips in America, in Germany the odds for walking relative to driving were 2.8 times higher; the odds for cycling relative to driving were14 times higher; and the odds for public transportation relative to driving were 2.6 times higher. For each increase of 1000 people per km^2 in population density the odds that a trip was by transit relative to the car were

1.3. The odds for trips by public transportation relative to driving for individuals living within 400m of a transit stop were 1.04 ($e^{0.04}$) the odds for households more than 1000m from a transit stop. This effect was very low and—as the next model with interaction effects showed—driven by the low effect of transit distance in the U.S. One explanation might be that this analysis did not include a transit level-of-service variable, as the distance to transit would indeed be theoretically insignificant if transit service were only provided once a day. The odds of a trip being by transit relative to the car for single employed individuals were 1.8 times the odds ($e^{0.532}$) for employed individuals in households with kids.

These effects for the pooled sample hid variability in direction and magnitude of coefficients between Germany and the U.S. Differences in effect of independent variables between the countries were presented in the next section of this dissertation.

The table below presents results for the final MNLM with interaction effects for the two countries. Pseudo-R^2s for the model ranged from 18.9 percent (McFadden) to 32.2 percent (Nagelkerke). Pseudo-R^2 for individual groups of independent variables were (models not shown here): 9.6 to16.4 percent for policy variables, 10.3 to 18.4 percent for land use variables, 14.0 to 25.3 percent for socioeconomic and demographic variables, and from 11.0 to 19.0 percent for the trip purpose variables. As in Chapter 8, and nine groups of independent variables were entered subsequently in the modeling process. McFadden's R^2 increased from 9.6 percent for the policy variables, 10.2 percent for policy and land use variables, 15.2 percent for policy, land use, socioeconomic, and demographic variables to finally reach 18.9 percent for all groups of independent variables together. Similar to the models in Chapter 8 and 9, the coefficients for household distance to a transit stop dropped significantly once the spatial development variables were included. Obviously, transit access and spatial development were closely connected, as transit provision was most viable in dense areas.

Model fit can also be assessed based on sensitivity and specificity of predicted and observed outcomes. For the choice car vs. transit 86 percent of car trips were correctly predicted to be by car and not by transit (sensitivity); 50 percent of transit trips were rightfully predicted to be by transit and not by car (specificity). For the choice car vs. bike 68 percent of car trips were predicted correctly (sensitivity); 75 percent of bike trips were predicted correctly (specificity). For the choice car vs. walk 80 percent of car trips was predicted correctly (sensitivity); and 75 percent of walking trips were predicted correctly (specificity).

According to the LR test the H_0 that all βs are equal to zero could be rejected for the final model. As above, the likelihood ratio chi-square test of the incremental fit attributable to the inclusion of each group of independent variables showed that they all contributed to the model.

Table 10.3 Dependent Variable: Mode Choice (Model with Interaction Effects)

		Mode of Transport		
		Transit	**Bike**	**Walk**
	Constant	**-3.763**	**-5.022**	**-1.968**
		(32.99)**	(26.01)**	(32.46)**
	Germany(1/0)	**1.322**	**3.907**	**1.512**
		(8.79)**	(18.40)**	(17.70)**
Policy	Transit access <400m	**0.044**	**0.082**	**0.194**
		-0.83	-0.82	(5.87)**
	Transit access <400m G	**0.514**	**-0.039**	**0.307**
		(6.33)**	-0.35	(6.22)**
	Transit access 400-1000m	**-0.193**	**-0.106**	**0.003**
		(2.72)**	(0.85)	(0.07)
	Transit access 400-1000m G	**0.503**	**0.114**	**0.299**
		(5.27)**	(0.85)	(5.23)**
Spatial development patterns	Population density	**0.149**	**0.085**	**0.156**
		(8.88)**	(2.52)*	(16.69)**
	Population density G	**0.243**	**-0.097**	**-0.04**
		(11.46)**	(2.69)**	(3.06)**
	Mix of use	**-0.133**	**0.137**	**0.282**
		(1.45)	-0.85	(5.24)**
	Mix of use G	**0.292**	**0.346**	**0.03**
		(1.98)*	(1.81)	(0.33)
Trip Purpose	Work trip	**0.397**	**-1.197**	**-1.255**
		(6.00)**	(7.68)**	(30.04)**
	Work trip G	**0.216**	**1.216**	**0.126**
		(2.84)**	(7.60)**	(2.33)*
	Shopping trip	**-1.915**	**-1.514**	**-1.225**
		(19.03)**	(10.75)**	(33.83)**
	Shopping trip G	**1.261**	**1.326**	**0.958**
		(11.64)**	(9.19)**	(22.79)**
Socioeconomic and demographic variables	Car access/availability	**-0.783**	**-0.304**	**-0.578**
		(11.16)**	(3.13)**	(14.02)**
	Car access/availability G	**-1.452**	**-1.391**	**-0.699**
		(15.11)**	(12.28)**	(11.73)**
	Household income	**-0.005**	**-0.002**	**-0.001**
		(7.49)**	(2.00)*	-1.28
	Household income G	**0.003**	**0.003**	**-0.006**
		(2.15)*	-1.89	(7.90)**
	Sex (Male=1)	**0.041**	**0.723**	**-0.014**
		(1.00)	(9.06)**	(0.53)
	Sex (Male=1) G	**-0.463**	**-0.729**	**-0.23**
		(8.85)**	(8.53)**	(6.84)**

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	Single HH with job	**0.569**	**0.386**	**0.459**
		(4.02)**	(1.52)	(6.93)**
	Single HH with job G	**0.057**	**0.068**	**-0.066**
		(0.34)	(0.25)	(0.70)
	Single HH without job	**1.192**	**0.797**	**0.828**
		(4.30)**	(1.76)	(6.05)**
	Single HH without job G	**-0.094**	**0.198**	**-0.429**
		(0.30)	(0.41)	(2.43)*
	Couple HH with job	**0.274**	**0.252**	**0.207**
		(2.66)**	-1.54	(4.83)**
	Couple HH with job G	**-0.363**	**-0.366**	**-0.134**
		(2.97)**	(2.08)*	(2.24)*
	Couple HH without job	**1.193**	**0.104**	**0.305**
		(6.60)**	(0.22)	(3.60)**
	Couple HH without job G	**-0.762**	**0.392**	**-0.019**
		(3.91)**	(0.81)	(0.20)
	HH, children without job	**0.679**	**-0.164**	**0.154**
		(4.32)**	(0.58)	(2.55)*
	HH, children without job G	**-0.168**	**0.376**	**-0.109**
		(0.98)	(1.30)	(1.47)
	Retired HH	**-0.156**	**-0.114**	**0.117**
		(1.14)	(0.76)	(2.77)**
	Retired HH G	**0.392**	**0.297**	**0.199**
		(2.71)**	(1.90)	(3.88)**
	Younger than 16/18	**2.884**	**1.69**	**0.575**
		(38.49)**	(15.42)**	(15.46)**
	Younger than 16/18 G	**-0.666**	**-0.154**	**0.558**
		(7.45)**	(1.30)	(11.25)**
Model Fit	Observations	343974		
	McFadden R-Square	18.9		
	Cox-Snell R-Square	25.5		
	Nagelkerke R Square	32.3		
	Log Likelihood Intercept	-271541.78		
	Log Likelihood Full	-223580.78		
	Probability> Chi Square	0.000		
Base outcome= car				
Absolute value of z statistics in parentheses * significant at 5%; ** significant at 1%				

(Data: respondents who traveled by car, transit, bicycle, or on foot during travel day)

As indicated above, the MNLM assumed independence of irrelevant alternatives (IIA). Outcomes for both Hausmann and Small-Hisao tests were mainly in favor of the H_0 that IIA was met.[139]

As mentioned above interpreting the coefficients from an MNLM was not straight forward. This was especially true for interaction effects. One cannot simply add the coefficients of the base variable and the interaction (Norton, Wang, & Ai, 2004). Jaccard (2001) suggested a—relatively complicated—solution to solve this problem. Results presented here were based on the joint model. Additionally, two separate models—one for Germany and one for the U.S.—were estimated and were presented in the appendix.

The odds of choosing the bike over the car in Germany were 49.7 times the odds in the U.S. ($e^{3.907}$). The odds of using public transportation were 275 percent higher in Germany than in the U.S. ($e^{1.322}$). Finally, in Germany the odds of walking instead of driving were 4.6 times the odds in the U.S. ($e^{1.512}$).

Living within 400m of a transit stop compared to households more than 1000m from a transit stop, increased the odds of using public transportation by 4.5 percent ($e^{0.044}$) in the U.S. The odds of using public transportation in Germany were 1.67 times the odds in the U.S. ($e^{0.514}$). This effect was very small for the U.S. One reason might be that in the U.S. the correlation between population density and transit access was much higher than in Germany, where transit service was also found in more rural areas. Therefore, the variable transit access might have lost some of its explanatory power for the U.S. once population density was controlled for. An analysis of two reduced models,

[139] The Hausmann test concluded that the model was a good fit for four out of four contrasts, and the Small-Hsiao estimated that the model was a good fit for two out of three contrasts. As above I followed McFadden's suggestion that the IIA assumption holds as the dependent variables can "*plausibly be assumed to be distinct and weighted independently in the eyes of the decision maker.*" This was also supported by a Wald test, which finds that the categories of the dependent variables are distinct.

one with transit distance only, and one with population density confirmed this. For Germany, the coefficient for transit distance changed only marginally once land use was removed. As expected, the magnitude of the effect of transit access was less pronounced for intermediate distances.

When density increased by 1000 people per km^2, the odds of making a trip by transit over the car increased by 16 percent ($e^{0.149}$) in the U.S. For each increase of 1000 people per km^2 the odds of using transit in Germany were 1.28 times the odds in the U.S. ($e^{0.243}$). Interestingly, population density did not have any effect on the odds of choosing the bike over the car in Germany.

Trips were more likely on foot in both countries in households living closer to a transit stop and in areas with greater land use mix. Work and shopping trips were less likely made on foot. In both, countries the probability to use public transportation, bike, or walk decreases with car ownership levels. The impact of gender on bike use between Germany and the U.S. was very different. In America, compared to trips made by women, the odds for bike trips made by men were 2.06 higher ($e^{0.723}$). In Germany women were just as likely to cycle as men. In the U.S. cyclists were mainly younger males.

Interestingly, in Germany retired individuals were more likely to use public transportation and cycle, while retirees in the U.S. were less likely to use these modes. Similarly, compared to the national averages, retirees were more likely to cycle in Germany and less likely to use their bike in the U.S. This might be connected to more dangerous cycling conditions in the U.S. (as highlighted in Chapter 4). Surveys have shown that women and the elderly prefer separate cycling facilities and highly value cycling safety (Garrard, Rose, & Lo, 2008).

Overall, this model predicted mode share well. For Germany the estimates were: 59.9 percent car use, 10.8 percent bicycling, 6.2 percent transit, and 23 percent walking. Transit and cycling are slightly low (-1.3 percent and -2 percent), while cycling and walking were slightly high (+1.8 percent and +1 percent).[140] The predictions for the U.S. were slightly worse and overestimated car use, while underestimating all other modes: 90.8 percent car (+3.8), 0.5 percent bike (-0.4 percent), 1.2 percent transit (-1.6 percent), and 6.5 percent walking (-2.5 percent). This might be related, as in the previous model, to the difficulty of modeling the large percentage of car use and the small shares for the other modes in the U.S.

The influence of different independent variables can also be interpreted as *marginal changes* in predicted probabilities. Effects of the independent variables on the dependent variables depend on the values of all independent variables, because probabilities in the MNLM models are non-linear and non-additive. Commonly, all variables were set at their mean and a marginal effect at the mean was reported for interval-ratio level variables (results are presented in the appendix). For example, setting all variables at their means revealed that a small change in level of mix of land uses in Germany reduced the probability of driving by 7.9 percent and increased the probabilities for walking (+4.1 percent), cycling (+3.2 percent), and transit use (+0.2 percent).[141] For

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[140]For the choice car vs. transit: 69 percent of car use predicted correctly (sensitivity), 81 percent of transit use predicted correctly (specificity). For the choice car vs. bike: 44 percent of car use predicted correctly (sensitivity), 84 percent of bike use predicted correctly (specificity). For the choice car vs. walk: 53 percent of car use predicted correctly (sensitivity), 76 percent of walking predicted correctly (specificity).

[141] For the choice car vs. transit: 90 percent of car use predicted correctly (sensitivity), 50 percent of transit use predicted correctly (specificity). For the choice car vs. bike: 97 percent of car use predicted correctly

the U.S., changes in predicted probability of a car trip were -1.6 percent; and +1.7 percent for walking. Cycling and transit use were almost not affected. Similarly, a small increase in population density decreased the probability of a car trip by 2.9 percent in Germany, but only by 1.1 percent in the U.S. For a small increase in population density, probabilities for walk trips increased by 0.9 percent in the U.S. and 1.5 percent in Germany respectively.

For nominal variables an interpretation of the discrete change from one category of the variable to another is more appropriate than a marginal effect. For example, compared to trips by adults, those by children and teenagers under driving age had a 34 percent lower probability to be made by automobile in Germany. This compared to a reduction of only 13 percent in the U.S. Similarly, retiring decreased the probability of traveling by car by 0.5 percent in the U.S. and by 6.5 percent in Germany.

10.2.1.1 Variations by Trip Distance

One might argue that the MNLM presented above is hiding important variations in mode choice by trips distance. Indeed, walking and cycling may be more appropriate modes of transportation for short distances, while public transportation may more likely be used for long trips. Two additional MNLM models were estimated to capture differences in mode choice by trip distance: one model for trips shorter than 1.6 kilometers (1mile) and one for trips longer than 16 kilometers (10 miles). These models were presented in the appendix and revealed some interesting differences and similarities in coefficients relative to the MNLM model presented above.

(sensitivity), 15 percent of bike use predicted correctly (specificity). For the choice car vs. walk: 70 percent of car use predicted correctly (sensitivity), 50 percent of walking predicted correctly (specificity).

For example, for short trips in Germany an increase of 1,000 people per km^2 in population density increased the odds of walking compared to driving by 1.23 times (compared to 1.12 for all trips). This is in line with expectations: population density at place of residence was more important in the decision to walk for short trips than for longer trips. In both countries, the odds of choosing public transportation over the car for a work trip were greater for longer than average trips (odds of 2.4 vs. 1.8 in Germany and 1.9 vs. 1.5 in the U.S.). This was also in line with expectations. Rail transit is most often geared towards commuting and rush hour traffic. Additionally, rail transit is faster for longer trip distances and thus more competitive compared to the car.

Bicycling had a stronger positive coefficient for the work trip in Germany for short trips than for all trips, indicating that the bicycle was more competitive compared to the car for short work trips. The odds of choosing the bike over the car were 2 for short trips compared to 1 for all trips.

Car ownership and access had a strong negative effect on walking, cycling, and transit use for all trip distances. Individuals who wish to drive by car might own more cars and therefore trip distance and availability of other modes do not matter.

The odds for trips by retired individuals to be made by public transportation declined with increasing trip distance in both countries (1.3 for short and 0.9 for long trips in Germany and 0.8 and 0.4 in the U.S.). One reason might be that retired individuals were more likely to travel shorter distances by transit, potentially by bus rather than by rail.

Overall trip distance seems to be an important intervening variable for mode choice. As expected the odds of choosing the bicycle or walking over the car were greater for short trips, while the odds to choose public transportation over the car were greater for longer trip distances.

10.2.2 Extension: Conditional Logit Model with Alternative Specific Data

So far all variables in the analysis pertained to trips made by individuals or their spatial surroundings. No variables describing optional or alternative transportation modes were included in the regression analyses, because these variables did not exist in the two national travel surveys. Other studies have shown that travel time and travel speed play an important role in mode choice and that individuals tend to choose faster over slower modes. Conditional logit models (CL) could capture mode choice if data on alternative transportation modes exist.[142] In contrast to the MNLM introduced previously, CL models include variables about the trip makers, the trips they made *and* the speed of potential travel alternatives. Estimating a CL model without mode specific variables would yield the same results as a MNLM.

Unfortunately, NHTS and MiD reported only travel speeds for trips made and consequently speeds of potential travel alternatives were unknown. To differentiate from the MNLM above, travel speeds for modes not chosen were imputed based on trip distance of the trip made and population density.

Imputation was not an ideal approach for including a speed variable into the CL model. Imputations by definition rely on assumptions and are only proxies for real

[142] CL models require manipulating the structure of the dataset, so that the data reflect the choice-set with travel speeds for all alternatives. This transformation is accomplished with the *case2alt* command in STATA, which transforms the data into the appropriate form. This transformation creates four observations for every trip. One observation represents the trip that was actually made and the other three observations contain travel speeds for the modes of transportation not chosen for this trip. All four observations display the same trip level data, such as distance or population density; but each observation contains the *specific travel speed for one mode of transportation* and information if this mode was chosen.

values.[143] Here, four different speed variables using two imputation techniques were imputed. Two different techniques were used for imputation in an attempt to capture variability in imputation outcomes for possible alternative travel speeds. First, alternative modes were assigned a travel speed based on national averages for a given mode and trip-distance category. For example, if a car trip of 3km length was made, then national average speeds of other modes for that particular trip distance served as a proxy for the unknown speeds of alternative modes. In this case the other modes were each assigned mode specific national averages for transit, cycling, or walking speeds for trips of 3km length.

Second, the other three imputed speed variables were based on a *hotdeck* imputation technique, which assigned speeds based on population density and trip distance (see Table 10.4). *Hotdeck* divided the data into categories according to population density and trip distance. For example, all car trip speeds for a certain trip distance and population density were assigned to one category. Trips with unknown alternative car speeds were randomly assigned a speed from all car trips in the relevant trip distance and population density category. The averages of the imputed speed variables are given in the table below.[144] Three *hotdeck* imputations were used to capture the variability in imputed alternative speeds.

The column labeled *base* displays average travel speeds by mode for all trips that were measured by the two surveys. The imputed values were different from the base values for two reasons. First, the distribution of trips for which the speed had to be imputed had an influence on average values. For example, car trips were generally

[143] Assumptions are explained in more detail further below.
[144] Due to the imputation techniques chosen, the range of the variables did not change. Standard deviations only changed marginally.

longer than other trips. Therefore the alternative car speed had to be imputed for a higher proportion of short trips (e.g. short walk or bike trips made by respondents). Speeds for short car trips were generally slower than for longer trips. This resulted in a lower average speed of the imputed variable. Second, imputations are never exact and therefore deviate from the real value.

Table 10.4Different Imputations for Alternative Travel Speeds (in km/h)

	Germany					USA				
	Base	*Average by Distance*	*Hotdeck #1*	*Hotdeck #2*	*Hotdeck #3*	*Base*	*Average by Distance*	*Hotdeck #1*	*Hotdeck #2*	*Hotdeck #3*
Car	31.0	25.8	26.2	26.2	26.2	39.9	38.0	37.2	37.1	37.2
Transit	18.2	12.2	13.9	13.8	14.1	21.9	15.5	20.9	20.8	20.9
Walk	4.4	4.8	5.5	5.5	5.6	5.1	5.0	6.9	7.1	7.2
Bike	10.7	11.7	12.2	12.4	12.3	9.3	12.1	13.4	13.3	13.2

These imputations were by no means perfect and relied on many assumptions. First, this imputation assumed that alternative trips would have the same trip length as the trip made. It is possible, however, that alternative modes have different trip distances to the same destination. For example, car trips might have longer trip distances as they include highway travel at high speeds, while a walk trip might be slower but use a more direct route. Similarly, transit trips might have longer trip distances due to the fixed route of transit services. Second, the imputations also assumed that other modes were real alternatives to the mode chosen. This might not always be the case. Public transportation, for example, was often not available. Additionally, walk or bike trips might not be feasible due to a lack of pedestrian or bicycling infrastructure. Third, the *hotdeck* imputations included population density at the place of residence, which was not relevant for trips not originating from home. Even though all these shortcomings existed, the speed variable could serve as a rough proxy for the role of travel speeds in mode choice.

Due to the size of the two transformed datasets and computational limitations, two separate models, one for Germany and one for the U.S. were estimated. Results are presented in Table 10.5 below. Simple t-tests of the coefficients for Germany and the U.S. helped determine if effects were significantly different between the countries (shaded in grey).

Table 10.5 Conditional Logit Models with Travel Speed Variable

		Germany / Mode of Transport			USA / Mode of Transport		
		Transit	**Bike**	**Walk**	**Transit**	**Bike**	**Walk**
	Constant	**-2.161**	**0.002**	**0.093**	**-3.398**	**-2.597**	**-0.448**
		(33.46)**	(0.04)	(2.05)*	(37.61)**	(19.37)**	(8.88)**
Policy	Transit access <400m	**0.598**	**-0.045**	**0.385**	**0.043**	**-0.114**	**0.032**
		(13.41)**	(1.49)	(14.48)**	(1.04)	(1.73)	(1.38)
	Transit access 400-1000m	**0.33**	**-0.063**	**0.262**	**-0.237**	**-0.244**	**-0.131**
		(7.12)**	(2.01)*	(9.56)**	(4.37)**	(2.80)**	(4.29)**
	Speed (all)	**0.073**			**0.069**		
		(125.08)**			(107.85)**		
	Speed (mode)	**0.043**	**-0.014**	**0.006**	**0.028**	**-0.108**	**0.019**
		(52.82)**	(6.40)**	(0.25)	(29.26)**	(14.73)**	(3.29)**
Spatial developme nt patterns	Population density	**0.357**	**-0.047**	**0.096**	**0.111**	**0.012**	**0.093**
		(39.83)**	(5.54)**	(14.74)**	(7.67)**	(0.58)	(14.29)**
	Mix of use	**0.222**	**0.103**	**-0.096**	**-0.086**	**-0.141**	**0.06**
		(2.76)**	(1.55)	(1.82)	(1.24)	(1.29)	(1.59)
Trip Purpose	Work trip	**0.725**	**0.211**	**-0.88**	**0.321**	**-0.906**	**-1.03**
		(23.00)**	(7.50)**	(32.00)**	(5.37)**	(8.38)**	(31.93)**
	Shopping trip	**-0.634**	**-0.41**	**-0.559**	**-1.996**	**-1.633**	**-1.39**
		(18.60)**	(16.49)**	(29.66)**	(25.29)**	(15.99)**	(47.95)**
Socioeconomic and demographic variables	Car access/availability	**-2.398**	**-1.571**	**-1.199**	**-0.722**	**-0.287**	**-0.494**
		(64.61)**	(51.08)**	(50.62)**	(19.64)**	(5.50)**	(23.59)**
	Household income	**-0.001**	**0.003**	**-0.004**	**-0.004**	**0.001**	**0.001**
		(1.47)	(4.29)**	(7.24)**	(7.87)**	(0.55)	(3.50)**
	Sex (Male=1)	**-0.394**	**0.079**	**-0.141**	**0.04**	**0.788**	**0.045**
		(17.62)**	(4.25)**	(9.52)**	-1.26	(14.70)**	(2.46)*
	Single HH with job	**0.837**	**0.509**	**0.599**	**0.702**	**0.309**	**0.407**
		(13.08)**	(8.40)**	(12.88)**	(6.78)**	(2.04)*	(9.48)**
	Single HH without job	**1.16**	**1.051**	**0.863**	**1.13**	**0.638**	**0.665**
		(11.70)**	(11.17)**	(10.47)**	(4.81)**	(2.01)*	(7.18)**
	Couple HH with job	**-0.033**	**-0.043**	**0.09**	**0.283**	**0.257**	**0.227**
		(0.68)	(1.10)	(2.94)**	(3.65)**	(2.52)*	(7.57)**
	Couple HH without job	**0.109**	**0.35**	**0.402**	**1.13**	**0.082**	**0.28**
		(2.18)*	(9.42)**	(13.52)**	(8.04)**	(0.34)	(4.72)**
	HH, children without job	**0.227**	**0.13**	**0.238**	**0.747**	**-0.214**	**0.136**
		(4.88)**	(3.48)**	(8.30)**	(6.50)**	(1.17)	(3.20)**
	Retired HH	**0.038**	**0.056**	**0.385**	**-0.271**	**-0.328**	**-0.07**
		(1.14)	(2.08)*	(18.63)**	(2.86)**	(3.02)**	(2.38)*
	Younger than 16/18	**2.035**	**1.243**	**1.172**	**3.218**	**1.617**	**0.546**
		(64.78)**	(47.25)**	(53.55)**	(49.09)**	(20.75)**	(20.45)**
Model Fit	Observations	599118			743365		
	McFadden Roh	36.40%			75.00%		
	Log Likelihood Intercept	-186529.398			-256895.94		
	Log Likelihood Full	-117663.51			-65080.098		
	Probability > Chi Square	0.000			0.000		

Base outcome = car
Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%, shaded in grey: difference of coefficients significant at 5%

Model fit for CL was assessed through a measure similar to R^2 (*McFadden's Roh*), which reached 75.0 percent for the U.S. and 36.4 percent for the German model.[145] The main variables of interest in this analysis were the speed variables. As expected, in both countries speed had a positive influence on the likelihood of choosing a mode. For all trips, a 1km/h increase in travel speed of any given mode compared to other modes increased the odds of choosing that mode by 7.6 percent (= $e^{0.073}$) in Germany and 7.3 percent (= $e^{0.069}$) in the U.S. The mode specific interaction variables for speed indicated whether the effect of speed of that particular mode was stronger or weaker than the average effect of speed. In both countries, the effect of a 1km/h increase in transit speed was larger than the average effect of speed: the odds of using transit compared to the car were 1.043 times larger than that for all modes in Germany (= $e^{0.043}$) and 1.028 times larger in the U.S. (=$e^{0.028}$). In both countries the odds of choosing the bike over the car decreased as bike speed increased. This was contradictory to expectations, but might be explained by the mainly recreational bike trip purposes. For recreational trips the bike did not compete with the car. Individuals purposefully chose the bike for their workout or leisure, which a car trip could not provide. Travel speed of an alternative car trip did not matter in this decision. Other explanations might lie in the imputation, omitted variables, or non-rational decision making of individuals.[146,147] Faster walk speeds in both countries increased the likelihood of choosing to walk over the car.[148]

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[145] Unfortunately, R^2s could not be compared between MNLM and CL models, as the change in data structure (generating four observations for every trip) inflated the R^2 (*Roh*) in the CL compared to MNLM.
[146] In fact, it can be argued that individuals did not necessarily make rational decisions when it comes to transportation mode choice. More recently, some scholars have been trying to incorporate the concept of bounded rationality into transportation planning models. Other disciplines, such as organizatinal theory, have accepted bounded rationality for a long time (Kieser 2001). For transportation decision making bouned rationality means that the concept of maximizing utility is challanged by the fact that: (1) individuals are often not aware of all potential alternatives available to them (Broeg and Erl 2008); (2) social norms and joy riding increase car use not for the sake of maximizing utility, but to satisfy social

10.3 Simulation

Similar to Chapters 8 and 9, Table 10.6 below displays predicted mode shares of car travel in Germany and the U.S. based on simulations from the MNLM. Mode shares for transit, cycling, and walking were not depicted in Table 10.6, but will be cited in the following narrative. Setting all variables at their average values, the model predicted 59.7 percent and 90.8 percent of trips by car in Germany and the U.S. respectively. The prediction was slightly lower than the real car mode share for Germany. On the other hand, the model predicted a three percent higher share of car use in the U.S. than found in the NHTS. Predicted mode shares for transit, cycling and walking were: 6.2 percent (transit), 10.8 percent (cycling), and 23.1 percent (walking) for Germany and 1.2 percent (transit), 0.5 percent (cycling), and 6.5 percent (walking) for the U.S. Mode choice models generally have problems predicting small percentage shares, such as transit use and cycling in the U.S., which were both predicted to be lower than they are in reality. Overall, the simulations confirmed the findings from the bi-variate analysis that most groups in the U.S. made the majority of their trips by car.

Household distance from a transit stop only had a very small impact on car mode split in the U.S. The majority of trips in households close to a transit stop were still made

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comparisons and self representation; (3) habitual behavior: individuals make the same travel decision every day and discount information and changes in the transportation environment. (Aveneri and Prashker 2004, Garling and Axhausen 2003).

[147] Omitted variables might include health benefits from walking and cycling, such as daily exercise.

[148] Model estimations with the hotdeck imputation resulted in a range of 0.036 to 0.041 for speed in Germany, compared to 0.033 to 0.037 in the U.S. Interaction effects for transit ranged from 0.003 to 0.04 in Germany and from -0.011 to -0.012 for the U.S. Interactions effects for bike speed ranged from -0.018 to -0.025 in Germany. Interaction effects for cycling speed in the USA, as well as walking speed in Germany and the U.S. indicated that faster speeds result in a lower probability to choose these modes. This is contradictory to expectations, but might be either explained by imputation problems, by omitted variables, or by irrational choices made by individuals.

by car.[149] In Germany, 43 percent of trips by individuals living close to transit were made by either transit, bike, or on foot.

The biggest similarity for car mode spilt existed for trips by individuals in households with 1.5 or more cars per driver. Ninety-three percent of trips by individuals in these households were estimated to be made by car in the U.S. compared to 83.4 percent in Germany. In these households less than five percent of trips were made by bike or by transit in both countries. Overall, car ownership had a large impact on car mode share in Germany. For example, 70 percent of trips by Germans in households with more cars than drivers were made trips by automobile (91 percent in the U.S.). This was a mode share twice as high as for the car-less in both countries. The high mode share of car use for the car-less in the U.S. hinted at an auto-dependent transportation system, where accessibility without a car was very limited.

The largest difference between the car mode share estimates for the two countries was among children and teenagers under driving age. In the U.S. the estimates showed that 80 percent of trips by children/teenagers were made as passengers of automobiles.[150] In Germany, this was just a little over 30 percent of all trips of children/teenagers. The mode share of trips of children in Germany were predicted to be: 30 percent on foot (9 percent for the U.S.), 19.5 percent by bike (1.8 percent for the U.S.), and 19.5 percent by public transportation (9.9 percent for the U.S.).

Simulations with the CL model estimated the effect of travel speed on mode choice. If all the modes in Germany had the same speed as in the U.S., 82 percent of all trips in Germany would be made by car. This result hinted at the importance of

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[149] Even though the 90 percent estimate is too high the NHTS confirms that individuals in households within 400m of a transit stop make over 80 percent of their trips by car.
[150] This value is very close to 78 percent car use, which was presented in the descriptives.

German policies that limit car travel speeds relative to other modes. The descriptive statistics have shown that transit, bike, and walk speeds are similar in the two countries, but that average car speeds were about 30 percent faster in the U.S. than in Germany, which lend that mode a competitive advantage. Therefore, the estimated percentage change in mode share in Germany assumed a significant increase in car travel speeds.

Table 10.6 Simulation Results: Impact of Independent Variables on Percentage of Trips Made by Car in Germany and the U.S.

Base Case (all variables at their mean)			
	Germany	**USA**	**Difference Germany vs. USA**
All variables at averages	59.7	90.8	34%
Swapped averages (US model with German averages an vice versa)			
	Germany	**USA**	**Difference Germany vs. USA**
Swapped transport policy averages	68.9	89.2	23%
Swapped spatial development pattern averages	64.0	88.7	28%
Swapped socioeconomic and demographic variables	75.4	89.5	16%
Swapped averages	80.6	86.9	7%
Effect of Individual Transport Policy Variables			
	Germany	**USA**	**Difference Germany vs. USA**
Transit farther than 1000m, other as base case	66.2	92.4	28%
Transit within 400-1000m, other as base case	61.3	92.1	33%
Transit within 400m, other as base case	57.4	90.8	37%
Effect of Individual Spatial Development Pattern Variables			
	Germany	**USA**	**Difference Germany vs. USA**
Density=1000, other as base case	64.0	91.8	30%
Density=2500, other as base case	60.1	90.0	33%
Density=5000, other as base case	51.1	86.0	41%
Mix of use=0.25, other as base case	60.6	91.9	34%
Mix of use=0.5, other as base case	58.6	91.5	36%
Mix of use=0.75, other as base case	56.5	91.0	38%
Effects of Individual Socioeconomic and Demographic Variables			
	Germany	**USA**	**Difference Germany vs. USA**
Cars per HH member= 0.5, other as base	52.7	88.5	40%
Cars per HH member= 1, other as base	70.5	91.2	23%
Cars per HH member= 1.5, other as base	83.4	93.3	11%
HH income= 10,000, other as base case	55.9	91.1	39%
HH income= 35,000, other as base case	58.5	91.8	36%
HH income= 75,000, other as base case	62.4	92.0	32%
Child/teenager=1, other as base case	31.1	79.4	61%
Female=1, other as base case	62.4	91.6	32%
Female=0, other as base case	57.4	91.9	38%
Retired=1, other as base case	62.6	93.2	33%
Work trip	64.6	94.3	31%
Other trip	55.6	87.5	36%
Shopping trip	62.6	96.3	35%

10.4 Conclusion

The main finding from this analysis was the greater car dependence of all groups of society in the U.S. Compared to the U.S., there was greater variability in mode split in Germany according to all groups of independent variables. In the U.S. more than 75 percent of trips were by automobile for nearly all socioeconomic and demographic groups, at all distances from transit, at all population densities, for all mix of use categories, for most trip distance categories, and for nearly all trip purposes. Even the majority of trips by children without a driver's license were by car.

Second, the bivariate and multivariate analyses and simulations yielded consistent results concerning most stated hypothesis. Living closer to a transit stop, at higher population densities, and in areas with a greater mix of land uses were associated with a lower share of car trips in both countries. Higher incomes and easier access to an automobile were connected to more car use. As the speed of a mode of transportation increased relative to other modes it becomes more likely that the faster mode was chosen.

Third, the empirical results also supported most of the hypotheses about differences in the strength of the coefficients of independent variables. Distance to a transit stop and population density had a weaker influence on car mode share in the U.S. compared to Germany. Income, gender, and access to an automobile, on the other hand, had a stronger influence on the car mode share in Germany. Major differences in mode shares for transit use and bicycling existed between the countries. In Germany, all groups of society cycled and used public transportation more than Americans. Four notable differences existed: first, compared to trips by other adults, trips by the elderly were more likely to be by public transportation and by bike in Germany. Second, in the U.S., trips by men were much more likely to be by bike than those by women; and trips by the elderly were less likely by transit or bike than trips by average Americans. Third, in the U.S. men and women both used the car for a similar share of trips. But there was a large gender gap in Germany. Men were more likely to drive than women there. Fourth, children and teenagers in the U.S. made a much higher share of their trips by car than their peers in Germany.

Additionally, the bivariate analysis showed that similar people or similar spatial development patterns in both countries did not lead to identical travel behavior. For example, the highest income quartile in Germany made a smaller share of trips by car than the lowest income quartile in the U.S. Germans living at low densities made a smaller share of trips by car and more trips by bike than Americans at high densities. The simulations confirmed these findings.

Chapter 9 showed that transportation policies and spatial development patterns had a stronger influence on car travel distance in the U.S. than in Germany. These factors seem to have a stronger influence on mode choice in Germany than in the U.S. In the U.S., most trips were made by automobile, no matter if a household was in a dense area, close to transit or the speed of the car is relatively less competitive for a certain car trip or distance. In Germany the probability of choosing a mode other than the car was higher for households in mixed use and dense areas, close to transit, and if other modes were faster than the car. This difference might be connected to overall more car-dependent settlement structure in the U.S. Often trips are not feasible by other modes than the car, as there were no facilities for walking and cycling, or as transit service was very limited. Even in dense areas many Americans had to drive as the destination of their trip was not accessible without a car. Higher levels of car ownership and higher car speeds in the U.S. helped to make car travel easier and more attractive compared to other modes there than in Germany. Automobile ownership played an important role in Germany; individuals in households with more cars than drivers showed automobile mode splits of 70 percent to 83 percent.

11 CONCLUSION

11.1 The Role of Transportation Policies, Spatial Developments Patterns, and Socioeconomic and Demographic Factors for Sustainable Transport

Over the last 50 years Germany and the U.S. have displayed similar trends of increasing car ownership and use. In 2007, the U.S. had the highest and Germany the fourth highest car ownership rate in the world.[151] Mobility in Germany and the U.S. have developed on two different levels, however. In 2002, Americans owned 35 percent more cars per capita and drove 125 percent more kilometers per capita than Germans. Dissimilar levels of car use have resulted in differences in the sustainability of the two countries' transportation systems. For example, in 2005 road transportation in the U.S. used about three times more energy, produced about three times more CO_2 emissions, and caused twice as many traffic fatalities per capita than in Germany.

This dissertation investigated the influence of transportation policies, spatial development patterns, and socioeconomic and demographic factors on individual travel behavior in Germany and the U.S. The purpose was to gain a better understanding of how to combat unsustainable trends in transportation, such as environmental pollution, oil dependence, obesity, traffic congestion, and road fatalities. A more sustainable transportation system can only be achieved if transportation policies, spatial development patterns, individual decisions, and their interdependence are understood. Therefore, this analysis included two parts: (1) a descriptive and qualitative examination of differences

[151] Only Luxemburg and New Zealand surpassed German motorization levels.

between the two countries in travel trends and transportation policies over time; and (2) a multivariate analysis based on two comparable national travel data sets.

The descriptive analysis showed that U.S. policies and institutions at all levels of government have been more favorable toward the automobile than in Germany. This has contributed to making car use much cheaper, easier, and more common in the U.S. than in Germany. First, all levels of government in the U.S. have prioritized funding for highways over all other modes of transportation, whereas Germany has had a more balanced funding approach to all modes of transportation. Second, car use is much cheaper, easier, and more convenient in the U.S. than in Germany, due to a lack of U.S. policies limiting car use or making it more expensive. Third, the density, mix of land uses, and compactness of German settlements also help to explain Germany's lower levels of car use. These features of German settlements have been fostered by strict land-use planning laws and an integrated spatial planning system. Fourth, in both countries socioeconomic and demographic factors play an important role in determining travel behavior. However, even controlling for socioeconomic and demographic indicators, such as income, car ownership, and household composition, Americans made more trips by car and drove more kilometers than their German counterparts. Thus, transportation policies and spatial development patterns play an important role in explaining differences in travel behavior and can help improve the sustainability of transportation systems.

Multivariate analyses showed that—depending on the modeling approach used—transportation policies explained between four and nine percent of the variability in travel behavior; spatial development patterns accounted for four and 10 percent, and socioeconomic and demographic variables explained between six and 14 percent.

The policy implications that follow from this research are: (1) higher population density, a greater mix of land uses, and access to public transportation are connected to reduced automobile use and car travel distance in both countries; (2) higher gasoline prices are linked to reduced car travel distance in both countries; (3) higher levels of car ownership have proven to be related to more car use in both countries; (4) more road supply and higher car travel speeds were associated with more automobile use; (5) a combination of car-restrictive policies with measures at all levels of government to increase the attractiveness of non-automobile modes has been key to more limited car use in Germany.

11.2 A More Favorable Policy Environment for Car Use in the U.S.

Both the U.S. and Germany have long histories of government involvement in the urban passenger transportation sector through regulation, taxation, and subsidies. The transportation policy environments in the two countries have grown along different paths historically, and their policy choices display many differences. Both targeted transportation and non-transportation-related policies account for the dissimilar transportation systems and travel behavior in the two countries. Overall, U.S. policies and institutions on all levels of government have been more favorable toward the automobile, and this has contributed to making car use much cheaper, easier, and more common in the U.S. than in Germany.

First, all levels of government in the U.S. have prioritized funding for highways over all other modes of transportation. In contrast, Germany has had a more balanced funding approach to all modes of transportation. Over the last 45 years, road user taxes and fees in the U.S. have consistently accounted for about 60 to 70 percent of roadway expenditures by all levels of government. From 1950 to 1980 Germany also subsidized highways. Since the mid 1980s, however, revenues from German road users have outweighed roadway expenditures by all levels of government. In 2005, roadway user taxes and fees were 260 percent of roadway expenditures in Germany.

One explanation for the differences in funding priorities between the countries lies in the institutional framework for collection and disbursement of highway user taxes and fees. In the U.S., most roadway user fees and taxes have been dedicated to federal or state Highway Trust Funds earmarked for roadway investments or maintenance. Public transportation and other modes of transportation have received an increasing share of subsidies from Highway Trust Funds, but most of the revenues have gone towards roadway construction and maintenance. In Germany, all tax revenues, including revenues from the gasoline tax, are by law part of the general fund. Consequently, roadway expenditures have to compete with other government investments for moneys from the general fund. This institutional setup in Germany has made the gasoline tax a welcome financing tool for other government investments. For example, gas tax increases in the 1990s helped to finance German reunification. These gas tax increases did not primarily target travel behavior, but made car use more expensive and therefore less attractive.

Higher subsidies for roads, less concentrated metropolitan areas, and larger distances between settlements have led to a higher road supply per capita in the U.S. than in Germany. More road supply per vehicle is connected to less congestion and higher average car travel speeds. In 2001/2002, average car travel speeds were about 25 percent higher in the U.S. than in Germany (41km/h compared to 33km/h). The multivariate analysis showed that faster car travel speeds result in more car use in both countries. Generally speaking, a one km/h increase in average car travel speeds was estimated to led to a seven percent increase in the likelihood of choosing the car over other modes of transportation. Simulations demonstrated that car use in Germany would increase from 60 to 80 percent of all trips if German average car speeds were to reach U.S. levels.

Furthermore, Germany also has a longer history of subsidies for public transportation than the U.S. Public ownership of transit agencies in Germany started as early as the late 19th century, when Bismarck nationalized the Prussian railroads (Dunn, 1981). By the end of WWII, all German transit agencies were publicly owned, and they have been subsidized by local, state, and federal governments ever since. In the U.S. at the end of WWII, most transit agencies were still privately owned. Transit systems—which had been heavily used during the war and were badly in need of reinvestment and repair—had to compete against increasing automobile ownership and use fuelled by government highway subsidies and suburban housing construction. Transit systems cut back services, lost riders, abandoned lines, tore out rails, and finally went out of business. It was only in the late 1960s and 1970s that the U.S. federal government started subsidizing public transportation. However, this aid came much too late to save many transit systems, which already had been disassembled in many cities.

Although today transit agencies in both countries are subsidized, Germany has been more efficient in using its subsidies. In 2002, for example, government subsidies comprised 35 percent of the operating budgets for public transit systems in Germany, but a full 60 percent of public transit operating budgets in the U.S. Total subsidies—for operations and investments—per rider and per passenger kilometer were 50 percent lower in Germany than in the U.S. One of the reasons for these differences in efficiency lies in the size of German transit networks, which provide access to multiple destinations and attract many passengers. In the U.S., most rail transit systems tore out tracks and cut back services after WWII and therefore provide smaller networks and access to fewer destinations. As a result transit supply was much more widespread in Germany in 2001/2002, with about 90 percent of households living within 1000 meters of public transit compared to only 43 percent of households in the U.S. The multivariate analysis showed that individuals that live near a transit stop make fewer trips by car and drive shorter distances in both countries. This effect was stronger in Germany than the U.S., most likely due to Germany's more extensive transit systems and higher levels of service. In the U.S., individuals living near transit still drove for nearly 80 percent of their trips, reflecting transit systems' generally limited accessibility to destinations.

Since the late 1960s, federal, state, and local governments have increasingly provided funds for non-motorized transportation in Germany. For example, from 1980 to 2000 the German federal government contributed over €1 billion to build bike paths along federal roadways. In the U.S. passage of the Intermodal Surface Transportation Efficiency Act *(ISTEA)* in 1991 resulted in increased federal funds for cycling and walking. At first glance, this change in legislation seemed to constitute a convergence of U.S. federal policies toward the more balanced transportation funding priorities exhibited in Germany. However, even since passage of ISTEA, all levels of government have continued to subsidize highways. State and local governments have not made full use of newly gained funding flexibility and have only spent a fraction of the funds available for non-motorized transportation.

<u>Second,</u> car use is much cheaper, easier, and more convenient in the U.S. than in Germany. During the last 45 years, a series of policy choices at the federal, state, and local levels in Germany have restricted automobile use and simultaneously increased the attractiveness and quality of public transportation, walking, and cycling. In the U.S., policies that limit car use are rarely implemented and measures that make other modes of transportation more attractive are generally more limited in scope.

In 2002, the ownership costs of an automobile were about 50 percent higher and operating costs per km were twice as high in Germany as in the U.S. These higher costs in Germany were caused by higher registration fees, and higher sales and gasoline taxes. For example, from 1960 to 2005, the share of taxes in the price of a liter of gasoline in the U.S. was between 20 and 30 percent. During the same period in Germany taxes represented between 60 and 80 percent of the price at the pump. The trends in the share of tax in the price of a liter of gasoline have been diverging in the two countries: the share of taxes in the price of gasoline has increased in Germany, but it has decreased in the U.S. High fuel taxes and higher registration fees for more polluting cars have augmented the demand for more fuel efficient vehicles in Germany. In contrast, the U.S. has focused on regulation of automobile manufacturers to improve fuel efficiency and tailpipe emissions, which has not impacted individual car travel through higher prices. Both approaches—taxation in Germany and manufacturer regulation in the U.S.—have led to increased fuel efficiency, but at different levels. In 2005, the American vehicle fleet was still less fuel efficient than the German fleet of 1980. The multivariate analysis showed that higher automobile operating costs were associated with fewer kilometers of car travel in both countries: a 10 percent increase in automobile operating cost decreased car travel distance by two percent in both countries.

Since the 1960s, German cities and regions have made car use less attractive and more expensive through a host of restrictions at the local level. Prior to the 1960s and 1970s, German cities, like their American counterparts, adapted their urban development to car use by widening roads, building car parking facilities in downtown areas, and allowing limited access highways to be built in some cities. Growing public discontent with the externalities of the automobile led to a change in policies, from accommodation of the automobile in cities to promotion of transit and prioritization of non-motorized modes of transportation in some parts of cities. Since the 1970s, most cities in Germany have traffic-calmed their residential neighborhoods, implemented car-free pedestrian zones in downtowns, and reduced the availability of automobile parking, while increasing its cost. These automobile-restrictive policies were accompanied by improvements in other modes of transportation. For example, German cities improved their transit services, constructed networks of bike paths and lanes, and improved their pedestrian environment. As a result, walking, cycling, and transit have become safe and convenient modes of transportation. In 2005, walking and cycling were three times safer in Germany than in the U.S. Public transportation has also greatly improved its quality, reliability and level of service over the last 45 years. Furthermore, since the late 1960s, most German cities have integrated the fares, timetables, and operations of their transit services on a regional basis. These regional transit organizations—called *Verkehrsverbund*—have proven very successful in increasing transit patronage.

As described in Chapter 4, there are many other policies and programs that make car use more expensive and other modes of transportation more attractive in Germany. For example, in 2007, the average cost of obtaining a driver's license was slightly less than $2,000 (€1,500) in Germany. This high cost was related to strict regulations and requirements for driver's training. In the U.S., costs for driver's licenses varied by state, but were generally much lower than in Germany. High costs for a driver's license were a potential deterrent to obtaining a license immediately upon reaching driving age. At the same time, German school children participated in bicycle training courses in the third and fourth grade, giving them bicycling skills and familiarizing them with this non-motorized mode of transportation at a very young age. This gives them a head start to a lifetime of cycling.

The two-pronged approach of restricting car use, while improving conditions for other modes of transportation has proven successful in limiting automobile use in German cities. Improving non-automobile transportation has been crucial in implementing car-restrictive policies. These policies were made acceptable by providing viable alternatives to the automobile. Some of these policies and institutional arrangements have also existed in the U.S. Particularly since passage of ISTEA, U.S. cities, regions, and states have been experimenting with improvements to public transportation and facilities for walking and cycling. These efforts have been more limited in scope than in Germany and—probably more importantly—were rarely supported by policies that restrict car use.

Anti-car policies might be harder to implement in the U.S. due to the largely positive public perception of the automobile, which seems to focus almost exclusively on the mobility benefits the automobile provides. In Germany the automobile seems to be more strongly associated with negative externalities in cities, including air pollution, noise, and more recently CO_2 emissions, thus making policies that restrict car use politically feasible.

Third, the density, mix of land uses, and compactness of German settlements also help to explain the country's lower levels of car use compared to the U.S. The differences in spatial development patterns between the two countries have been shaped by differences in their geography, spatial and transportation planning systems, property rights, and local finance structures.

In Germany, federal, state, and local governments participate in a top-down and bottom-up interactive planning process. At all levels of government, land-use planning is formally connected to transportation and other areas of planning. For example, the German Federal Ministry of Transportation is also responsible for spatial planning (Bundesministerium fuer Verkehr, Bau, und Stadtentwicklung), thus formally integrating transportation and land-use planning.

In the U.S., there is no equivalent to Germany's federal ministry of spatial planning. Land-use planning is effectively in the domain of municipalities, which often compete for new residential development to increase their property tax bases. In Germany, property taxes are less important for local governments, as they receive more revenues from state and federal governments. German federal law limits spatial expansion of settlements to areas adjacent to already developed areas. If developers want to develop property outside of already existing settlements, they must provide justification for the need to locate the development at a distance from existing settlements. In the U.S., the opposite is the case. Individuals have the right to develop their property and governments must justify why development should not occur.

Local land-use planning in both countries involves the separation of land uses. German zoning categories are less stringent than standard in American practice. For example, residential areas in Germany may include small hotels, doctor's offices, and small corner stores—uses commonly banned in areas zoned for single family residences in the U.S. In addition, the German federal government mandates special approval procedures for large malls built outside of already developed areas, thus making large retail suburbanization more difficult. Maintenance of denser settlements with a greater mix of land uses keeps travel distances shorter and makes them feasible on foot or by bike. At the same time, automobile travel speeds are reduced due to lower road supply per capita in dense areas. Thus, higher population density and a diverse mix of land uses are important in making car use less attractive, while at the same time increasing the feasibility and convenience of other modes of transportation.

The multivariate analysis showed that households in denser and more mixed-use developments make fewer and shorter car trips in both countries. Individuals living in dense areas in the U.S. still made a higher share of their trips by car than Germans living in areas of similar and lower population densities. This is most likely related to the U.S.'s lower regional population densities and the fact that access to areas outside the immediate dense surroundings of homes in the U.S. is often difficult or impossible without a car.

Since 1970, many U.S. states and cities have been experimenting with new land-use planning processes, tools, and techniques, such as state plans, growth boundaries, form-based zoning codes, and smart growth. However, these approaches are generally far less restrictive and comprehensive than the German spatial planning system.

Fourth, the multivariate analysis also showed that in both countries socioeconomic and demographic factors accounted for a large share of variability in travel behavior. For all social groups, mobility levels were higher in the U.S. For some distributions of socioeconomic and demographic variables, indicators for travel behavior in the two countries did not even overlap. For example, in 2001/2002, the lowest income quartile in the U.S. made a higher share of trips by car than the highest income quartile in Germany. There were also significant differences in travel behavior between some similar demographic groups in both countries. For example, in the U.S. children and teenagers made 77 percent of their trips as a passenger in an automobile. In Germany, on the other hand, teenagers and children used transit, walked or biked for 58 percent of their trips. Chauffeuring children also had an impact on the travel behavior of parents. In the U.S., adults in households with children drove more kilometers in a car than any other group, most likely due to additional trips made to transport their children. In Germany, the car use pattern of single households and families were similar.

Overall, car use was more evenly distributed among all groups of society in the U.S. For example, men and women in the U.S. made a comparable share of their trips by automobile, while in Germany, women made fewer car trips and drove fewer kilometers than men, most likely due to lower car ownership rates and more traditional roles for women as homemakers.[152] For bicycle, use the opposite trend was found, with more

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[152] Germany has a lower female workforce participation rate and a smaller share of women with driver's licenses than in the U.S. In particular elderly women in Germany did not have a driver's license. Younger women, however, were much more likely to have a license. It is therefore expected that the gender difference in travel behavior between the two countries will close over time.

widespread cycling among all groups of society in Germany. In the U.S., most cyclists were younger males, while in Germany, women cycled as much as men, and even individuals over 65 years old cycled for 12 percent of their trips.

In the U.S., 90 percent of the trips made by retired individuals were by automobile, while in Germany the car mode share was just 55 percent for retired individuals. There were two main factors that might be associated with this difference. First, the German transportation system offered more options for older citizens to access destinations without a car. Second, retired Germans were socialized before mass motorization and may therefore be more reluctant to drive car.

Overall, in the U.S. all demographic groups were more reliant on the automobile than their German counterparts due to the U.S.'s more auto-dependent transportation and land-use system. The built environment in the U.S. often made walking and cycling impossible and for many trips public transportation was not an option.

11.3 Implications for Policy and Planning

Based on these descriptive and multivariate analyses, several recommendations can be made on how to achieve a more sustainable transportation system and how best to promote more sustainable travel behavior in both countries.

First, higher population density, a greater mix of land uses, and access to public transportation reduce car travel frequency and car travel distances in both countries. Policies promoting more mixed-use and denser developments around transit stations can encourage changes in travel behavior, such as switching from driving to other modes of transportation and can help to reduce the total number of kilometers traveled by car.

Land use and transit access have a greater impact on *travel distance* in the U.S. than in Germany, while their impact on *mode choice* is stronger in Germany than in the U.S. The lower impact on mode choice in the U.S. is likely explained by lower regional population densities and more dispersed use of land, which renders many locations difficult to access without a car. Furthermore, the level of service and quality of public transportation is lower in the U.S., thus making transit a relatively less attractive transportation choice.

This research suggests that, in the U.S., policies geared toward increasing population density, the mix of land uses, and transit access can be successful in reducing car use and increasing walking, cycling, and transit use. The outcomes of such programs should be evaluated based on both changes in car travel distance and mode choice. It is likely that the effects on mode choice will initially be more limited, with people continuing to drive—but traveling shorter total daily distances. Developments around transit stops connecting to larger public transportation networks with multiple destinations and with higher levels of services will likely alter transportation mode choice more significantly.

In Germany, on the other hand, the impacts of dense development around transit stops on mode choice tend to be larger, as most transit systems provide access to multiple destinations with more service frequency. Thus, promoting transit-oriented development, around stops connecting to existing transit networks could be a successful way of reducing or limiting car use.

Second, gasoline prices have an effect on car travel distance in both countries. Cars with higher operating costs per kilometer were driven for fewer kilometers per day.

Demand elasticities for car travel distance were inelastic and similar in both countries (at negative |0.2|). A 10 percent increase in the price of a liter of gasoline decreases demand for car travel by two percent. Simulations showed that aggressively increasing automobile operating costs to German levels via gas tax increases in the U.S. would have a large impact on daily car travel distance (-30 percent).

The German policy approach showed that the potentially regressive impact of higher fuel prices on lower income households can be offset by expanding public transportation services and improving inexpensive non-motorized transportation, thus providing alternatives to driving. In addition, trends in Germany have shown that higher fuel prices increase the demand for more fuel efficient cars, which effectively reduce the cost per kilometer driven.

Third, car ownership has proven to be a crucial determinant of car use in both countries. German households with more cars than drivers displayed travel behavior similar to that of American households with multiple vehicles. German and American households with fewer cars than drivers displayed more disparate travel behavior patterns. Policies aimed at making car ownership more costly could be successful in limiting increases in car use in Germany. The analysis showed that households with high car ownership rates even drove for the majority of trips shorter than 1.6 kilometers in both countries.

Fourth, road supply and car speeds are important determinants of car use. For each additional km/h increase in car travel speed, Germans are seven percent more likely to choose the car over other modes of transportation. Simulations showed that if Germany were to have average car travel speeds as high as those of the U.S. in

2001/2002, then the mode share of car use would increase from 60 to 80 percent. While a 33 percent increase in average car speed in Germany is very unlikely, it confirms the importance of travel speed in making travel decisions. Therefore, restricting car speeds through speed limits, traffic calming, and a smaller supply of roads per vehicle, might be appropriate to help reduce car travel speeds and the attractiveness of the automobile compared to other modes.

Fifth, the combination of anti-car policies with measures that increase the attractiveness of non-automobile modes at all levels of government has been key to more limited car use in Germany. Traditionally higher costs of car use, a longer history of transit subsidies, and earlier policies promoting walking and cycling in Germany were important in shaping an environment that facilitates walking, cycling and transit use. Compared to Germany, policies in the U.S. that encourage non-automobile transportation were implemented on a smaller scale and were rarely supplemented with policies that limited car use. If U.S. policies toward transit use, walking, and cycling are to be successful, they will have to be combined with policies that make car use less attractive. These policies include gasoline taxes, registration fees, speed limits, traffic calming, reduction of and strategic pricing for car parking in cities, and limiting automobile access to downtowns. Of course such policies cannot be implemented overnight. An incremental approach is necessary with simultaneous improvements in the supply and quality of non-automobile transportation and accessibility.

11.4 Limitations of Multivariate International Comparative Analysis

International comparisons of travel behavior have traditionally been hampered by problems in the comparability of data or survey methods. Most studies in the past had to rely on country or city averages, which mask wide variability in individual travel behavior. The unique comparability of the German MiD and the U.S. NHTS surveys constitutes an unprecedented opportunity for individual level international comparisons. While some previously assumed relationships were confirmed through this study, other findings call into question the conventional wisdom. An individual level study of travel decisions was the only way to capture these differences.

The multivariate analysis revealed differences in the travel behavior of similar individuals and differences in the impact of spatial development patterns and policies on three dimensions of travel behavior. Socioeconomic and demographic variables explained between six and 14 percent of total variability in travel behavior. Policies and spatial development patterns also help to explain differences in travel behavior. Transportation policies explained between four and nine percent of the variability in the data and spatial development patterns accounted for four and 10 percent. Furthermore, interesting differences in the magnitudes of individual independent variables were shown. For example, population density and the mix of land uses have a stronger influence on mode choice in Germany than in the U.S.

In spite of the high comparability of the surveys, some recommendations for improvements of future travel surveys and analyses can be made. Most suggestions pertain to (1) better and more comparable data about individuals, their cars, and the built environment, and (2) more comparable time series data.

First, the study had to rely on cross-sectional data, as no time series data were available to compare travel behavior over time. Cross-sectional data are useful in providing a glimpse into differences in travel in both countries at one point in time.

However, to capture the impacts of variables like gasoline prices, transit access, or population density, observations would have to be measured over time. A time series study, ideally a panel study, could show how changes in policies or spatial development patterns effect changes in travel behavior over time. Cross-sectional analysis can only capture differences in policies and land uses across the sample at one point in time, but not over time.

Similarly, this study was successful in capturing differences in the sign, magnitude, and significance of the independent variables in each country. Differences between the countries were captured through simulations which set all variables at their average values and then manipulated single variables or groups of variables at a time. A multi-country time series study would be necessary to capture differences between countries more effectively.

A time series analysis might be possible soon, as in January 2008 the U.S. and German governments began collecting data for their NHTS and MiD 2008 surveys, which again use similar data collection methods and will include similar variables.

Second, endogeneity and self-selection bias are always problems for analyses of travel behavior. Endogeneity bias can occur (1) if independent variables are also a function of the dependent variable or (2) if independent variables are correlated with omitted variables (Handy et al. 2006). In both cases estimators will be biased and inconsistent. These two conditions are often encountered in transportation and land-use research. The built environment influences travel behavior, but at the same time, travel behavior impacts spatial development patterns over time. In this case, not accounting for the simultaneity of the influence might bias estimators. Furthermore, some researchers argue that the choice of household location and car ownership is associated with travel preferences and attitudes. Individuals who wish to travel less by car might own fewer cars and locate closer to transit stops or in areas with higher population densities and a more diverse mix of land uses. Not including specific variables about attitudes and travel preferences could lead to biased coefficients.

Several solutions exist to address these problems, such as statistical control, instrumental variable models, sample selection models, joint models, and longitudinal designs (see Handy et al. 2006). All of these approaches come with stringent requirements for comparability of variables and measurements in both countries and are hard to implement with just two cross-sectional surveys. Therefore, only three promising possibilities for future international comparative research will be highlighted here.

(1) A longitudinal study design could help to overcome these problems by providing "*before and after*" data on changes in individuals, travel behavior, and spatial development patterns. Such an analysis might be possible once NHTS and MiD 2008 data become available. Second, direct questioning of respondents about their travel preferences and attitudes could help control for self-selection bias.

(2) Both MiD and NHTS could include questions explicitly asking for individual travel preferences. Including these attitudinal variables would overcome a potential correlation of location choice and car ownership with the error term.

(3) Another possibility might lie in structural equation models (SEM), which allow for causation to flow in multiple directions among independent and dependent variables. SEM should ideally also include variables measuring travel preferences and attitudes. Unfortunately, SEM is based on the analysis of bivariate correlations, which is

problematic when applied to the large number of nominal and categorical variables included in this analysis. In practice, however researchers often use SEM with nominal and categorical values. Ideally, SEM could be combined with a longitudinal design capturing changes over time.

Sample selection bias is a problem for all travel surveys, but for comparative analysis in particular. Response rates for national and regional travel surveys generally range from 10 to 40 percent. Heckman Selection Models (HSM) helped account for the choice of making a trip on a given travel day, but no information was available about non-respondents in the two datasets. Limited non-response studies were carried out for both surveys and found the potential for selection bias. Both surveys included weights to adjust for the distributions of certain characteristics in the samples and the populations. Higher weights were assigned to the travel behavior of respondents with certain characteristics. In order to control for selection bias, both surveys could supply a file with the characteristics of the households that completed the initial household screening interview, but then dropped out before the data collection period. A HSM model could be used to control for the likelihood of participating in the survey in the first stage, and then analyze travel behavior in the second stage. This approach would not overcome potential selection bias for complete non-responders, but it would account for part of the selection bias.

Third, the two surveys were only representative for the countries as a whole and certain regions and states of each country. Unfortunately, they were not representative for specific cities and metropolitan areas. The aggregate nature of the two surveys might mask variability within specific metropolitan areas and cities within the two countries.

Dummy variables for states were used to help account for spatial variation, but these variables still remained on a relatively aggregate level. Ideally, the datasets would contain information about specific cities and regions and the specific neighborhood location of households within these regions. The U.S. data allow an analysis at the census tract level, but the German data were often only available on a more aggregate level. If more observations for metropolitan areas and the spatial development patterns of neighborhoods existed, similar metropolitan areas within the two countries could be compared

Fourth, socioeconomic and demographic variables were thoroughly measured by the two datasets, but spatial development and policy variables had to rely on rough proxies or aggregate indicators. For example, neither survey included information about the supply of transportation infrastructure and service or local accessibility. Household distance to major highways, and bike networks, and the frequency and quality of transit service could greatly enhance the analysis of mode choice decisions. Furthermore, one or two variables capturing local accessibility, such as distance to the closest supermarket and other facilities could be very helpful in describing spatial development patterns. Ideally, additional measures of transportation policies and policy outcomes such as parking fees, taxes on car purchase, the length of local road, bike and sidewalk networks, traffic safety, and perceived safety should have been included in this analysis. Unfortunately, these variables were not available at the level of the individual trip maker. Improvements in the measurement of spatial development patterns and policy variables will strengthen the accuracy of the models and might increase the portion of variability explained by these two groups of variables.

Fifth, the German survey was not easily accessible to the user. For the NHTS, the U.S. Department of Transportation provided the exact census tract location for each household. In Germany this information was not readily available, requiring additional steps to even begin the analysis. For example, spatial development indicators had to be collected for 14,000 German municipalities and were then submitted to a data clearinghouse, which merged the data to less than 400 municipalities with households included in the MiD survey. A process that gives researchers confidential access to a listing of household locations (at least the municipalities) would be helpful.

11.5 Implications for Transportation Theory

This analysis points to the important role of transportation policies in shaping travel behavior. Transportation and economic theory would suggest that people with similar social and economic attributes in Germany and the U.S. should display similar travel behavior. For example, households with higher incomes are expected to own more cars and to drive more, or, households in denser areas are predicted to drive less often and for fewer kilometers. The analysis showed that these theoretical expectations hold true within each country, but they do not hold true across countries. For example, Americans in the highest population density categories drive more kilometers by car than Germans in the lowest density category. Individuals in the highest income quartile use transit, walk, and cycle for a higher share of trips than the lowest income quartile in the U.S. Theories in travel behavior are correct, but they must consider other contextual factors that influence travel behavior. These contextual factors include transportation and land-use policies and culture.

Socioeconomic and demographic data are relatively easy to obtain on the individual and aggregate level. Data about transportation policies are difficult to obtain and hard to measure; therefore, they are rarely included in multivariate analysis. Even when they are included, researchers have to rely on rough indicators or proxies. This dissertation finds that socioeconomic and demographic variables account for the largest share of variability explained, but transportation policies and spatial development patterns also play a role.

Some transportation theorists believe Germany and other countries follow the U.S. in motorization and travel behavior with a 20 to 30 year time lag. They predict that increasing incomes and higher levels of car ownership in Germany will lead to increasingly similar travel behavior in Germany and the U.S. This analysis showed that, given the structural differences between the countries in the funding of transportation, settlement structure, public perception of automobile externalities, transportation policies, and land-use policies, it is unlikely that travel behavior in Germany will become like travel behavior in the U.S. For example, in 2005, Germans owned as many cars per capita as Americans in the late 1980s, but Germans in 2005 drove 50 percent fewer kilometers per capita than Americans in the late 1980s. Transportation and land-use policies have a mediating impact on the development of travel behavior. While Germany and the U.S. are generally headed in the same direction of higher levels of motorization and car use, these trends occur on different levels.

11.6 Achieving More Sustainable Transportation

Germany and the U.S. have shown trends toward unsustainable transportation with increasing automobile use over the last decades. This dissertation has shown that transportation policies and spatial development patterns have an important impact on individual travel choices and the externalities of the transportation system. If governments want to effectively mitigate the negative effects of the current transportation system, a comprehensive and multifaceted policy and funding approach involving all modes of transportation and spatial development patterns is necessary. First, technology improvements will have to play a role, especially for the automobile. Governments can set incentives to increase fuel efficiency, decrease tail-pipe emissions, and to increase the passive safety of drivers and passengers. Technology improvements alone will not be enough, however, as they do little to combat congestion, obesity, and pedestrian and cyclist fatalities. On the contrary, improving fuel efficiency might encourage driving via cheaper operating costs per kilometer. More kilometers of car travel might have the potential to even offset the energy consumption improvements made in fuel efficiency. Second, policies that encourage and promote walking, cycling, and public transportation should be implemented by all levels of government. Ideally, these three modes of transportation should be integrated to provide a viable alternative to the car. Federal government could provide financial incentives for other levels of government to achieve this. Third, policies that make car use more difficult, more expensive and less attractive must accompany these pro-transit, walking, and cycling policies. These policies could include higher gas taxes, higher registration fees, greater adherence to and more stringent speed limits, curtailing of highway subsidies, stricter enforcement of traffic laws, and reduced car parking in cities. The political feasibility of these relatively unpopular measures will crucially depend on the attractiveness, feasibility, and supply of alternative means of transportation. Fourth, these policies must be accompanied by incentives to keep settlements dense with mixed land uses. This will keep trip distances short and feasible on foot or by bike. Without the potential to reach destinations in a reasonable amount of time on foot, by bike, or by public transportation, the transportation policies described above will not be enough to be effective. Germany has already—intentionally or not—implemented many of these policies. This is precisely the reason why transportation there is more sustainable today. Both countries still have a long way to go to make their transportation systems more sustainable. Current conditions seem favorable for implementation of such policies at all levels of government. In the face of peak oil and climate change, Germans and Americans might be more open than ever before to changes in their transportation systems and travel behaviors.

Appendix Chapter 8

Appendix Table 8.1 Dependent Variable: Daily Travel Distance per Person in km; (Groups of Independent Variables Approach)

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Constant	**51.132** (158.39)**	**54.003** (135.59)**	**17.145** (27.72)**	**40.106** (226.33)**	**49.154** (189.56)**	**42.409** (50.21)**
Policy	Transit access <400m	**-17.654** (44.16)**					**-6.056** (13.08)**
	Transit access 400-1000m	**-16.136** (34.66)**					**-4.896** (9.47)**
Spatial development patterns	Population density		**-5.349** (46.07)**				**-1.938** (14.47)**
	Mix of use		**-13.194** (15.17)**				**-11.877** (13.79)**
Socioeconomics and demographics	Household Income			**0.102** (13.83)**			**0.091** (12.62)**
	Car access/availability			**13.338** (31.59)**			**5.066** (12.16)**
	Driver's License			**10.865** (24.23)**			**10.118** (22.81)**
	Younger than 16/18			**-9.414** (16.40)**			**-11.385** (20.11)**
	Single HH with Job			**-0.657** (0.81)			**0.063** (0.08)
	Single HH without Job			**-7.035** (4.45)**			**-6.44** (4.06)**
	Couple HH with Job			**2.142** (3.83)**			**0.374** (0.68)
	Couple HH without Job			**-10.897** (15.72)**			**-8.362** (12.27)**
	HH, Small Children with Job			**3.958** (5.89)**			**1.809** (2.76)**
	HH, Small Children without Job			**-5.866** (6.78)**			**-6.069** (7.17)**
	HH, Older Children without Job			**-6.252** (8.66)**			**-6.123** (8.61)**
	Retired HH			**-6.394** (12.74)**			**-6.841** (13.82)**
	Sex (Male=1)			**3.374** (14.24)**			**3.944** (16.78)**
Macro-economic differences	Sunday				**-0.356** (0.59)		**-1.165** (1.99)*
	Germany(1/0)					**-19.295** (58.61)**	**-10.216** (24.30)**
	Observations	**93102**	**91608**	**89780**	**93347**	**93347**	**87897**
	R-squared	**0.04**	**0.05**	**0.10**	**0.00**	**0.06**	**0.14**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%						

Appendix Table 8.2 Dependent Variable: LN (Daily Travel Distance per Person in km); (Sequential and block approach)

		Model 1	***Model 2***	***Model 3***	***Model 4***	***Model 5***
	Constant	**3.569** (381.12)**	**3.763** (286.94)**	**2.678** (90.36)**	**2.679** (90.14)**	**2.891** (95.79)**
Policy	Transit access <400m	**-0.658** (49.82)**	**-0.403** (25.54)**	**-0.312** (20.10)**	**-0.312** (20.10)**	**-0.217** (14.16)**
	Transit access 400-1000m	**-0.566** (36.46)**	**-0.373** (21.72)**	**-0.295** (17.53)**	**-0.295** (17.53)**	**-0.129** (7.52)**
Spatial developme nt patterns	Population density		**-0.126** (25.68)**	**-0.081** (16.52)**	**-0.081** (16.52)**	**-0.044** (8.75)**
	Mix of use		**-0.362** (12.42)**	**-0.333** (11.60)**	**-0.333** (11.60)**	**-0.332** (11.76)**
Socioeconomics and demographics	Household Income			**0.005** (21.83)**	**0.005** (21.82)**	**0.004** (18.69)**
	Car access/availability			**0.325** (23.42)**	**0.325** (23.42)**	**0.225** (16.71)**
	Driver's License			**0.591** (29.66)**	**0.591** (29.65)**	**0.6** (30.32)**
	Younger than 16/18			**-0.222** (9.66)**	**-0.222** (9.66)**	**-0.245** (10.73)**
	Single HH with Job			**0.107** (4.36)**	**0.107** (4.36)**	**0.03** (1.22)
	Single HH without Job			**-0.187** (2.99)**	**-0.186** (2.99)**	**-0.26** (4.15)**
	Couple HH with Job			**0.079** (4.88)**	**0.079** (4.88)**	**0.023** (1.44)
	Couple HH without Job			**-0.343** (13.68)**	**-0.343** (13.67)**	**-0.3** (12.07)**
	HH, Small Children with Job			**0.081** (4.27)**	**0.081** (4.27)**	**0.016** -0.88
	HH, Small Children without Job			**-0.194** (6.59)**	**-0.194** (6.59)**	**-0.211** (7.28)**
	HH, Older Children without Job			**-0.213** (8.79)**	**-0.213** (8.79)**	**-0.204** (8.47)**
	Retired HH			**-0.194** (12.10)**	**-0.194** (12.10)**	**-0.214** (13.54)**
	Sex (Male=1)			**0.114** (14.02)**	**0.114** (14.02)**	**0.126** (15.53)**
Macro-economic differences	Sunday				**-0.005** (0.23)	**-0.018** (0.92)
	Germany(1/0)					**-0.444** (29.47)**
	Observations	**98054**	**96242**	**92603**	**92603**	**92603**
	R-squared	**0.04**	**0.06**	**0.16**	**0.16**	**0.17**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%					

Appendix Table 8.3 Dependent Variable: Daily Travel Distance per Person in km; Including Non-Trip Makers (Sequential and block approach)

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Constant	3.569 (381.12)**	3.638 (285.69)**	2.031 (82.74)**	3.168 (517.56)**	3.522 (447.97)**	2.891 (95.79)**
Policy	Transit access <400m	-0.658 (49.82)**					-0.217 (14.16)**
	Transit access 400-1000m	-0.566 (36.46)**					-0.129 (7.52)**
Spatial developme nt patterns	Population density		-0.191 (45.93)**				-0.044 (8.75)**
	Mix of use		-0.389 (13.34)**				-0.332 (11.76)**
Socioeconomics and demographics	Household Income			0.005 (20.85)**			0.004 (18.69)**
	Car access/availability			0.511 (36.12)**			0.225 (16.71)**
	Driver's License			0.63 (31.74)**			0.6 (30.32)**
	Younger than 16/18			-0.173 (7.54)**			-0.245 (10.73)**
	Single HH with Job			0.027 (1.10)			0.03 (1.22)
	Single HH without Job			-0.253 (4.07)**			-0.26 (4.15)**
	Couple HH with Job			0.094 (5.76)**			0.023 (1.44)
	Couple HH without Job			-0.396 (15.81)**			-0.3 (12.07)**
	HH, Small Children with Job			0.103 (5.35)**			0.016 -0.88
	HH, Small Children without Job			-0.201 (6.79)**			-0.211 (7.28)**
	HH, Older Children without Job			-0.217 (8.96)**			-0.204 (8.47)**
	Retired HH			-0.196 (12.17)**			-0.214 (13.54)**
	Sex (Male=1)			0.105 (12.81)**			0.126 (15.53)**
Macro-economic differences	Sunday				0.003 (0.14)		-0.018 (0.92)
	Germany(1/0)					-0.762 (66.28)**	-0.444 (29.47)**
	Observations	98054	96488	94572	98307	98307	92603
	R-squared	0.04	0.05	0.13	0.00	0.07	0.17
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%						

		Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*
	Constant	**43.949** (144.99)**	**49.568** (121.20)**	**28.299** (38.80)**	**28.924** (39.63)**	**33.028** (44.01)**
Policy	Transit access <400m	**-15.455** (41.63)**	**-8.743** (20.63)**	**-6.725** (15.91)**	**-6.722** (15.90)**	**-4.715** (11.06)**
	Transit access 400-1000m	**-13.592** (31.31)**	**-8.459** (18.26)**	**-6.951** (15.05)**	**-6.978** (15.12)**	**-3.529** (7.36)**
Spatial development patterns	Population density		**-3.357** (28.47)**	**-2.408** (20.10)**	**-2.404** (20.03)**	**-1.668** (13.82)**
	Mix of use		**-10.669** (13.19)**	**-9.526** (11.82)**	**-9.544** (11.83)**	**-9.492** (11.86)**
Socioeconomics and demographics	Household Income			**0.123** (17.98)**	**0.123** (17.97)**	**0.11** (16.16)**
	Car access/availability			**7.15** (18.44)**	**7.165** (18.45)**	**5.027** (12.90)**
	Driver's License			**11.608** (31.62)**	**11.595** (31.54)**	**12.062** (32.86)**
	Younger than 16/18			**-8.097** (16.00)**	**-8.13** (16.06)**	**-8.468** (16.82)**
	Single HH with Job			**2.545** (3.26)**	**2.534** (3.25)**	**0.98** (1.26)
	Single HH without Job			**-7.14** (5.35)**	**-7.08** (5.30)**	**-8.702** (6.49)**
	Couple HH with Job			**1.378** (2.56)*	**1.396** (2.60)**	**0.227** (0.43)
	Couple HH without Job			**-11.297** (18.49)**	**-11.253** (18.43)**	**-10.445** (17.25)**
	HH, Small Children with Job			**3.467** (5.41)**	**3.468** (5.43)**	**2.075** (3.27)**
	HH, Small Children without Job			**-7.411** (9.48)**	**-7.407** (9.48)**	**-7.907** (10.20)**
	HH, Older Children without Job			**-8.207** (12.67)**	**-8.176** (12.64)**	**-8.15** (12.65)**
	Retired HH			**-8.38** (18.15)**	**-8.386** (18.21)**	**-8.889** (19.39)**
	Sex (Male=1)			**3.548** (16.45)**	**3.57** (16.55)**	**3.8** (17.66)**
Macro-economic differences	Sunday				**-4.469** (8.74)**	**-4.576** (9.05)**
	Germany(1/0)					**-9.077** (23.72)**
	Observations	**108508**	**106390**	**102032**	**102032**	**102032**
	R-squared	**0.03**	**0.05**	**0.12**	**0.12**	**0.13**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%					

Appendix Table 8.4Dependent Variable: Daily Travel Distance per Person in km; (Groups of Independent Variables Approach with Interaction)

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Constant	**43.949** (144.99)**	**46.673** (125.01)**	**11.855** (21.77)**	**34.949** (211.95)**	**42.529** (173.93)**	**33.028** (44.01)**
Policy	Transit access <400m	**-15.455** (41.63)**					**-4.715** (11.06)**
	Transit access 400-1000m	**-13.592** (31.31)**					**-3.529** (7.36)**
Spatial development patterns	Population density		**-4.757** (45.08)**				**-1.668** (13.82)**
	Mix of use		**-11.165** (13.80)**				**-9.492** (11.86)**
Socioeconomics and demographics	Household Income			**0.116** (16.86)**			**0.11** (16.16)**
	Car access/availability			**12.154** (31.69)**			**5.027** (12.90)**
	Driver's License			**12.073** (33.06)**			**12.062** (32.86)**
	Younger than 16/18			**-7.071** (13.97)**			**-8.468** (16.82)**
	Single HH with Job			**0.389** (0.50)			**0.98** (1.26)
	Single HH without Job			**-8.718** (6.57)**			**-8.702** (6.49)**
	Couple HH with Job			**1.877** (3.47)**			**0.227** (0.43)
	Couple HH without Job			**-12.309** (20.14)**			**-10.445** (17.25)**
	HH, Small Children with Job			**4.106** (6.33)**			**2.075** (3.27)**
	HH, Small Children without Job			**-7.434** (9.50)**			**-7.907** (10.20)**
	HH, Older Children without Job			**-7.939** (12.23)**			**-8.15** (12.65)**
	Retired HH			**-8.194** (17.70)**			**-8.889** (19.39)**
	Sex (Male=1)			**3.301** (15.29)**			**3.8** (17.66)**
Macro-economic differences	Sunday				**-4.25** (8.31)**		**-4.576** (9.05)**
	Germany(1/0)					**-17.168** (56.22)**	**-9.077** (23.72)**
	Observations	**108508**	**106670**	**104298**	**108795**	**108795**	**102032**
	R-squared	**0.03**	**0.04**	**0.10**	**0.00**	**0.05**	**0.13**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%						

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Policy	Transit access <400m	**-12.977** (23.72)**					**-6.599** (9.75)**
	Transit access <400m G	**7.25** (8.18)**					**3.763** (3.91)**
	Transit access 400-1000m	**-7.822** (9.44)**					**-5.346** (6.15)**
	Transit access 400-1000m G	**4.788** (4.36)**					**3.211** (2.87)**
Spatial development patterns	Population density		**-4.114** (22.88)**				**-2.559** (11.50)**
	Population density G		**2.623** (10.64)**				**1.432** (5.13)**
	Mix of use		**-14.399** (13.54)**				**-12.816** (11.73)**
	Mix of use G		**-0.945** (0.53)				**-0.315** (0.18)
Socioeconomic and demographic variables	Household income			**0.07** (8.23)**			**0.079** (9.31)**
	Household income G			**0.043** (2.83)**			**0.044** (2.93)**
	Car access/availability			**6.434** (12.53)**			**3.313** (6.40)**
	Car access/availability G			**4.41** (5.38)**			**5.742** (7.03)**
	Driver's License			**13.844** (17.34)**			**11.71** (14.28)**
	Driver's License G			**-5.593** (5.91)**			**-3.629** (3.77)**
	Younger than 16/18			**-10.96** (11.79)**			**-12.913** (13.64)**
	Younger than 16/18 G			**1.195** (1.04)			**2.93** (2.52)*
	Sex (Male=1)			**2.857** (7.86)**			**2.894** (7.90)**
	Sex (Male=1) G			**2.361** (5.05)**			**2.396** (5.09)**

Socioeconomic and demographic variables	Single HH with job			**-6.261** (5.80)**			**-2.866** (2.60)**
	Single HH with job G			**8.73** (5.46)**			**7.085** (4.37)**
	Single HH without job			**-15.151** (5.76)**			**-13.326** (5.01)**
	Single HH without job G			**12.456** (3.83)**			**12.87** (3.93)**
	Couple HH with job			**-1.649** (2.07)*			**-0.703** -0.88
	Couple HH with job G			**3.173** (2.90)**			**2.059** -1.89
	Couple HH without job			**-7.659** (4.71)**			**-7.114** (4.34)**
	Couple HH without job G			**-0.116** (0.07)			**-0.375** (0.21)
	HH, small children with job			**1.225** (1.31)			**1.672** (1.80)
	HH, small children with job G			**-0.969** (0.75)			**-1.138** (0.88)
	HH, small children without job			**-6.158** (4.37)**			**-5.862** (4.11)**
	HH, small children without job G			**-0.054** -0.03			**-0.042** -0.02
	HH, older children without job			**-7.276** (5.77)**			**-7.721** (6.07)**
	HH, older children without job G			**2.793** -1.86			**3.073** (2.04)*
	Retired HH			**-9.623** (11.81)**			**-10.07** (12.33)**
	Retired HH G			**5.055** (5.00)**			**5.985** (5.91)**
Macro-economic differences	Sunday				**-1.019** (1.19)		**-1.033** (1.16)
	Sunday G				**-0.196** (0.17)		**-0.365** (0.32)
	Germany(1/0)	**-20.247** (27.69)**	**-19.615** (25.39)**	**-19.717** (14.90)**	**-19.29** (56.07)**	**-19.295** (58.61)**	**-23.84** (14.34)**
	Constant	**54.24** (151.75)**	**58.503** (115.11)**	**32.436** (30.65)**	**49.29** (181.25)**	**49.154** (189.56)**	**46.951** (38.16)**
	Observations	**93102**	**91608**	**89780**	**93347**	**93347**	**87897**
	R-squared	**0.07**	**0.07**	**0.12**	**0.06**	**0.06**	**0.14**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%						

Appendix Table 8.5 Dependent Variable: LN(Daily Travel Distance per Person in km); (Sequential and Block Approach with Interaction)

		Model 1	***Model 2***	***Model 3***	***Model 4***	***Model 5***
	Constant	**3.522** (447.97)**	**3.671** (366.84)**	**3.837** (255.43)**	**3.145** (79.30)**	**3.144** (79.06)**
Policy	Transit access <400m		**-0.406** (23.13)**	**-0.173** (8.23)**	**-0.161** (7.63)**	**-0.161** (7.63)**
	Transit access <400m G		**0.092** (2.92)**	**-0.105** (3.10)**	**-0.05** (1.52)	**-0.05** (1.52)
	Transit access 400-1000m		**-0.177** (7.07)**	**-0.07** (2.71)**	**-0.092** (3.51)**	**-0.092** (3.52)**
	Transit access 400-1000m G		**0.019** (0.52)	**-0.073** (1.95)	**-0.042** (1.15)	**-0.042** (1.15)
Spatial development patterns	Population density			**-0.106** (13.85)**	**-0.088** (11.31)**	**-0.088** (11.32)**
	Population density G			**0.092** (8.66)**	**0.089** (8.37)**	**0.09** (8.40)**
	Mix of use			**-0.393** (11.87)**	**-0.383** (11.54)**	**-0.383** (11.54)**
	Mix of use G			**-0.084** (1.20)	**-0.006** (0.09)	**-0.007** (0.10)
Socioeconomic and demographic variables	Household income				**0.003** (13.89)**	**0.003** (13.89)**
	Household income G				**0.003** (5.95)**	**0.003** (5.96)**
	Car access/availability				**0.136** (8.90)**	**0.136** (8.90)**
	Car access/availability G				**0.314** (10.03)**	**0.315** (10.05)**
	Driver's License				**0.557** (18.75)**	**0.557** (18.76)**
	Driver's License G				**-0.01** (0.26)	**-0.01** (0.26)
	Younger than 16/18				**-0.294** (9.37)**	**-0.294** (9.37)**
	Younger than 16/18 G				**0.013** (0.29)	**0.013** (0.28)
	Sex (Male=1)				**0.095** (8.82)**	**0.095** (8.82)**
	Sex (Male=1) G				**0.071** (4.36)**	**0.071** (4.38)**

Socioeconomic and demographic variables	Single HH with job				**-0.04** (1.34)	**-0.04** (1.34)
	Single HH with job G				**0.209** (4.04)**	**0.208** (4.03)**
	Single HH without job				**-0.502** (5.38)**	**-0.502** (5.38)**
	Single HH without job G				**0.487** (3.88)**	**0.487** (3.89)**
	Couple HH with job				**0.023** (1.13)	**0.023** (1.13)
	Couple HH with job G				**0.012** (0.35)	**0.011** (0.34)
	Couple HH without job				**-0.255** (5.47)**	**-0.255** (5.47)**
	Couple HH without job G				**-0.036** (0.64)	**-0.035** (0.63)
	HH, small children with job				**0.024** (1.03)	**0.024** (1.03)
	HH, small children with job G				**-0.037** (0.94)	**-0.037** (0.94)
	HH, small children without job				**-0.206** (5.00)**	**-0.206** (5.00)**
	HH, small children without job G				**0.001** (0.01)	**0.001** (0.01)
	HH, older children without job				**-0.294** (8.12)**	**-0.294** (8.12)**
	HH, older children without job G				**0.146** (3.03)**	**0.147** (3.03)**
	Retired HH				**-0.249** (11.29)**	**-0.249** (11.29)**
	Retired HH G				**0.074** (2.34)*	**0.074** (2.34)*
Macro-economic differences	Sunday					**0.007** -0.26
	Sunday G					**-0.063** (1.55)
	Germany(1/0)	**-0.762** (66.28)**	**-0.688** (27.19)**	**-0.68** (20.25)**	**-1.074** (17.40)**	**-1.067** (17.27)**
	Observations	**98307**	**98054**	**96242**	**92603**	**92603**
	R-squared	**0.07**	**0.08**	**0.09**	**0.18**	**0.18**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%					

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Constant	**3.671** (366.84)**	**3.817** (257.66)**	**2.681** (72.48)**	**3.524** (428.06)**	**3.522** (447.97)**	**3.144** (79.06)**
Policy	Transit access <400m	**-0.406** (23.13)**					**-0.161** (7.63)**
	Transit access <400m G	**0.092** (2.92)**					**-0.05** (1.52)
	Transit access 400-1000m	**-0.177** (7.07)**					**-0.092** (3.52)**
	Transit access 400-1000m G	**0.019** (0.52)					**-0.042** (1.15)
Spatial development patterns	Population density		**-0.136** (21.26)**				**-0.088** (11.32)**
	Population density G		**0.111** (11.34)**				**0.09** (8.40)**
	Mix of use		**-0.423** (12.94)**				**-0.383** (11.54)**
	Mix of use G		**-0.095** (1.37)				**-0.007** (0.10)
Socioeconomic and demographic variables	Household income			**0.003** (13.01)**			**0.003** (13.89)**
	Household income G			**0.004** (6.47)**			**0.003** (5.96)**
	Car access/availability			**0.23** (14.96)**			**0.136** (8.90)**
	Car access/availability G			**0.265** (8.46)**			**0.315** (10.05)**
	Driver's License			**0.643** (21.86)**			**0.557** (18.76)**
	Driver's License G			**-0.085** (2.12)*			**-0.01** (0.26)
	Younger than 16/18			**-0.228** (7.31)**			**-0.294** (9.37)**
	Younger than 16/18 G			**-0.039** (0.86)			**0.013** (0.28)
	Sex (Male=1)			**0.128** (15.72)**			**0.095** (8.82)**
	Sex (Male=1) G			**0.081** (4.38)**			**0.071** (4.38)**

Socioeconomic and demographic variables	Single HH with job			**-0.143** (4.95)**			**-0.04** (1.34)
	Single HH with job G			**0.29** (5.70)**			**0.208** (4.03)**
	Single HH without job			**-0.539** (5.79)**			**-0.502** (5.38)**
	Single HH without job G			**0.486** (3.88)**			**0.487** (3.89)**
	Couple HH with job			**-0.01** (0.51)			**0.023** (1.13)
	Couple HH with job G			**0.052** (1.58)			**0.011** (0.34)
	Couple HH without job			**-0.269** (5.83)**			**-0.255** (5.47)**
	Couple HH without job G			**-0.031** (0.56)			**-0.035** (0.63)
	HH, small children with job			**0.004** (0.17)			**0.024** (1.03)
	HH, small children with job G			**-0.009** (0.24)			**-0.037** (0.94)
	HH, small children without job			**-0.204** (4.97)**			**-0.206** (5.00)**
	HH, small children without job G			**-0.021** (0.37)			**-0.001** (0.01)
	HH, older children without job			**-0.285** (7.86)**			**-0.294** (8.12)**
	HH, older children without job G			**0.135** (2.80)**			**0.147** (3.03)**
	Retired HH			**-0.24** (10.83)**			**-0.249** (11.29)**
	Retired HH G			**0.06** (1.91)			**0.074** (2.34)*
Macro-economic differences	Sunday				**-0.016** (0.60)		**0.007** (0.26)
	Sunday G				**-0.027** (0.67)		**-0.063** (1.55)
	Germany(1/0)	**-0.688** (27.19)**	**-0.816** (29.09)**	**-0.924** (17.84)**	**-0.759** (63.43)**	**-0.762** (66.28)**	**-1.067** (17.27)**
	Observations	**98054**	**96488**	**94572**	**98307**	**98307**	**92603**
	R-squared	**0.08**	**0.09**	**0.17**	**0.07**	**0.07**	**0.18**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%						

Appendix Table 8.6 Dependent Variable: Daily Travel Distance per Person in km; Including Non-Trip Makers (Sequential and block approach with Interaction)

		Model 1	***Model 2***	***Model 3***	***Model 4***	***Model 5***
Policy	Transit access <400m		**-11.413** (22.24)**	**-5.676** (9.03)**	**-5.19** (8.20)**	**-5.185** (8.18)**
	Transit access <400m G		**7.108** (8.76)**	**2.821** (3.16)**	**3.333** (3.76)**	**3.332** (3.76)**
	Transit access 400-1000m		**-6.161** (7.75)**	**-3.432** (4.22)**	**-4.037** (4.89)**	**-3.997** (4.84)**
	Transit access 400-1000m G		**4.714** (4.57)**	**2.649** (2.54)*	**3.105** (2.97)**	**3.013** (2.89)**
Spatial development patterns	Population density			**-2.69** (13.71)**	**-2.231** (11.04)**	**-2.227** (10.97)**
	Population density G			**1.454** (5.85)**	**1.279** (5.06)**	**1.285** (5.07)**
	Mix of use			**-11.293** (11.11)**	**-10.427** (10.17)**	**-10.449** (10.18)**
	Mix of use G			**-1.025** (0.62)	**-0.289** (0.18)	**-0.279** (0.17)
Socioeconomics and demographics	Household income				**0.096** (11.85)**	**0.096** (11.83)**
	Household income G				**0.036** (2.57)*	**0.036** (2.59)**
	Car access/availability				**3.247** (6.62)**	**3.242** (6.61)**
	Car access/availability G				**5.203** (6.92)**	**5.246** (6.97)**
	Driver's License				**16.442** (25.02)**	**16.426** (24.94)**
	Driver's License G				**-8.151** (10.46)**	**-8.153** (10.44)**
	Younger than 16/18				**-9.19** (10.95)**	**-9.208** (10.97)**
	Younger than 16/18 G				**2.044** (2.00)*	**1.993** -1.95
	Sex (Male=1)				**3.067** (8.99)**	**3.076** (9.01)**
	Sex (Male=1) G				**1.735** (4.01)**	**1.769** (4.08)**

Socioeconomics and demographics	Single HH with job				**-2.212** (2.04)*	**-2.202** (2.04)*
	Single HH with job G				**6.141** (3.99)**	**6.067** (3.95)**
	Single HH without job				**-17.082** (7.96)**	**-17.08** (7.96)**
	Single HH without job G				**15.852** (5.83)**	**15.959** (5.87)**
	Couple HH with job				**-1.776** (2.23)*	**-1.751** (2.21)*
	Couple HH with job G				**3.139** (2.97)**	**3.111** (2.95)**
	Couple HH without job				**-13.578** (9.49)**	**-13.471** (9.40)**
	Couple HH without job G				**5.831** (3.72)**	**5.748** (3.67)**
	HH, small children with job				**0.551** (0.60)	**0.554** (0.61)
	HH, small children with job G				**1.254** (1.00)	**1.238** (0.99)
	HH, small children without job				**-10.608** (8.09)**	**-10.614** (8.10)**
	HH, small children without job G				**5.173** (3.26)**	**5.189** (3.28)**
	HH, older children without job				**-12.069** (10.40)**	**-11.994** (10.36)**
	HH, older children without job G				**7.174** (5.24)**	**7.093** (5.19)**
	Retired HH				**-14.143** (18.31)**	**-14.16** (18.37)**
	Retired HH G				**9.468** (10.05)**	**9.485** (10.09)**
Macro-economic differences	Sunday					**-4.069** (5.03)**
	Sunday G					**-1.059** (1.06)
	Germany(1/0)	**-17.168** (56.22)**	**-18.753** (28.02)**	**-17.049** (19.33)**	**-19.391** (13.16)**	**-19.312** (13.13)**
	Constant	**42.529** (173.93)**	**46.936** (138.21)**	**51.586** (103.29)**	**35.649** (32.63)**	**36.252** (33.17)**
	Observations	**108795**	**108508**	**106390**	**102032**	**102032**
	R-squared	**0.05**	**0.05**	**0.06**	**0.14**	**0.14**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%					

		Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
	Constant	**46.936** (138.21)**	**50.797** (104.84)**	**23.568** (25.83)**	**43.086** (167.03)**	**42.529** (173.93)**	**36.252** (33.17)**
Policy	Transit access <400m	**-11.413** (22.24)**					**-5.185** (8.18)**
	Transit access <400m G	**7.108** (8.76)**					**3.332** (3.76)**
	Transit access 400-1000m	**-6.161** (7.75)**					**-3.997** (4.84)**
	Transit access 400-1000m G	**4.714** (4.57)**					**3.013** (2.89)**
Spatial development patterns	Population density		**-3.677** (22.44)**				**-2.227** (10.97)**
	Population density G		**2.316** (10.36)**				**1.285** (5.07)**
	Mix of use		**-12.286** (12.22)**				**-10.449** (10.18)**
	Mix of use G		**-0.558** -0.34				**-0.279** (0.17)
Socioeconomic and demographic variables	Household income			**0.088** (10.97)**			**0.096** (11.83)**
	Household income G			**0.035** (2.51)*			**0.036** (2.59)**
	Car access/availability			**5.946** (12.38)**			**3.242** (6.61)**
	Car access/availability G			**3.975** (5.31)**			**5.246** (6.97)**
	Driver's License			**17.831** (28.07)**			**16.426** (24.94)**
	Driver's License G			**-9.174** (12.12)**			**-8.153** (10.44)**
	Younger than 16/18			**-7.893** (9.62)**			**-9.208** (10.97)**
	Younger than 16/18 G			**1.136** (1.14)			**1.993** (1.95)
	Sex (Male=1)			**3.891** (18.12)**			**3.076** (9.01)**
	Sex (Male=1) G			**2.194** (5.06)**			**1.769** (4.08)**

Socioeconomic and demographic variables	Single HH with job			**-4.984** (4.72)**			**-2.202** (2.04)*
	Single HH with job G			**7.439** (4.91)**			**6.067** (3.95)**
	Single HH without job			**-18.372** (8.70)**			**-17.08** (7.96)**
	Single HH without job G			**15.484** (5.76)**			**15.959** (5.87)**
	Couple HH with job			**-2.539** (3.23)**			**-1.751** (2.21)*
	Couple HH with job G			**4.093** (3.88)**			**3.111** (2.95)**
	Couple HH without job			**-13.504** (9.64)**			**-13.471** (9.40)**
	Couple HH without job G			**5.542** (3.60)**			**5.748** (3.67)**
	HH, small children with job			**0.172** (0.19)			**0.554** (0.61)
	HH, small children with job G			**1.496** (1.20)			**1.238** (0.99)
	HH, small children without job			**-10.333** (8.06)**			**-10.614** (8.10)**
	HH, small children without job G			**4.312** (2.78)**			**5.189** (3.28)**
	HH, older children without job			**-11.201** (9.82)**			**-11.994** (10.36)**
	HH, older children without job G			**6.338** (4.69)**			**7.093** (5.19)**
	Retired HH			**-13.566** (17.73)**			**-14.16** (18.37)**
	Retired HH G			**8.535** (9.12)**			**9.485** (10.09)**
Macro-economic differences	Sunday				**-3.91** (5.05)**		**-4.069** (5.03)**
	Sunday G				**-1.212** (1.25)		**-1.059** (1.06)
	Germany(1/0)	**-18.753** (28.02)**	**-17.575** (24.48)**	**-14.981** (13.13)**	**-17.028** (52.81)**	**-17.168** (56.22)**	**-19.312** (13.13)**
	Observations	**108508**	**106670**	**104298**	**108795**	**108795**	**102032**
	R-squared	**0.05**	**0.06**	**0.12**	**0.05**	**0.05**	**0.14**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%						

Appendix Chapter 9

Appendix Table 9.1 Dependent Variable: Daily Car Travel Distance per Person in km; Groups of Independent Variables Approach

		Model 1	***Model 2***	***Model 3***	***Model 4***	***Model 5***	***Model 6***
	Constant	**64.862** (130.84)**	**56.503** (130.42)**	**24.281** (29.15)**	**43.616** (217.99)**	**50.949** (189.65)**	**54.374** (44.11)**
Policy	Transit access <400m	**-10.41** (22.31)**					**-5.991** (11.50)**
	Transit access 400-1000m	**-8.398** (15.33)**					**-5.226** (8.96)**
	Operating Cost per km of Car Travel	**-2.332** (34.08)**					**-1.155** (8.48)**
Spatial development patterns	Population density		**-5.227** (38.21)**				**-2.261** (13.54)**
	Mix of use		**-13.365** (14.22)**				**-12.298** (12.73)**
Socioeconomics and demographics	Household Income			**0.087** (10.99)**			**0.071** (8.84)**
	Car access/availability			**11.474** (24.68)**			**3.734** (7.83)**
	Driver's License			**6.759** (10.61)**			**5.851** (8.56)**
	Younger than 16/18			**-10.673** (14.23)**			**-13.707** (17.48)**
	Single HH with Job			**-0.303** (0.34)			**0.467** (0.51)
	Single HH without Job			**-5.122** (2.36)*			**-4.297** -1.73
	Couple HH with Job			**2.229** (3.75)**			**0.227** (0.39)
	Couple HH without Job			**-8.23** (9.78)**			**-5.551** (6.67)**
	HH, Small Children with Job			**4.435** (6.22)**			**2.315** (3.31)**
	HH, Small Children without Job			**-3.595** (3.66)**			**-3.805** (3.89)**
	HH, Older Children without Job			**-5.573** (6.79)**			**-5.366** (6.60)**
	Retired HH			**-4.995** (8.97)**			**-5.408** (9.69)**
	Sex (Male=1)			**2.974** (11.03)**			**3.966** (14.62)**
Macro-economic differences	Sunday				**1.524** (2.27)*		**1.072** (1.54)
	Germany(1/0)					**-17.824** (48.64)**	**-4.635** (5.38)**
	Observations	**73070**	**74945**	**73074**	**76094**	**76094**	**69302**
	R-squared	**0.06**	**0.04**	**0.06**	**0.00**	**0.04**	**0.11**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%						

Appendix Table 9.2 Dependent Variable: LN(Daily Car Travel Distance per Person in km); (Sequential and block approach)

		Model 1	Model 2	Model 3	Model 4	Model 5
	Constant	**4.029** (290.21)**	**4.132** (257.59)**	**3.615** (99.31)**	**3.598** (98.81)**	**3.537** (94.39)**
Policy	Transit access <400m	**-0.297** (21.65)**	**-0.19** (12.30)**	**-0.179** (11.49)**	**-0.179** (11.50)**	**-0.168** (10.81)**
	Transit access 400-1000m	**-0.222** (13.43)**	-0.154 (8.91)**	-0.146 (8.42)**	-0.146 (8.41)**	-0.127 (7.24)**
	Operating Cost per km of Car Travel	**-0.073** (34.45)**	**-0.064** (28.44)**	**-0.056** (23.35)**	**-0.055** (23.18)**	**-0.034** (7.98)**
Spatial developme nt patterns	Population density		**-0.065** (12.76)**	**-0.06** (11.54)**	**-0.06** (11.66)**	**-0.057** (10.85)**
	Mix of use		**-0.352** (12.52)**	**-0.354** (12.47)**	**-0.355** (12.54)**	**-0.358** (12.63)**
Socioeconomic and demographic variables	Household Income			**0.003** (12.58)**	**0.003** (12.62)**	**0.003** (12.02)**
	Car access/availability			**0.154** (11.41)**	**0.154** (11.44)**	**0.14** (10.24)**
	Driver's License			**0.262** (11.30)**	**0.265** (11.46)**	**0.269** (11.63)**
	Younger than 16/18			**-0.462** (17.96)**	**-0.46** (17.93)**	**-0.463** (18.08)**
	Single HH with Job			**0.029** (1.22)	**0.029** -1.23	**0.024** -0.99
	Single HH without Job			**-0.103** -1.35	**-0.106** -1.38	**-0.115** -1.5
	Couple HH with Job			**0.03** -1.94	**0.031** -1.95	**0.025** -1.59
	Couple HH without Job			**-0.232** (9.07)**	**-0.233** (9.11)**	**-0.229** (8.95)**
	HH, Small Children with Job			**0.049** (2.72)**	**0.049** (2.73)**	**0.042** (2.33)*
	HH, Small Children without Job			**-0.125** (4.30)**	**-0.124** (4.28)**	**-0.128** (4.44)**
	HH, Older Children without Job			**-0.206** (8.62)**	**-0.207** (8.66)**	**-0.208** (8.72)**
	Retired HH			**-0.138** (8.70)**	**-0.137** (8.67)**	**-0.145** (9.13)**
	Sex (Male=1)			**0.136** (16.73)**	**0.135** (16.69)**	**0.134** (16.45)**
Macro-economic differences	Sunday				**0.093** (4.63)**	**0.092** (4.57)**
	Germany(1/0)					**-0.165** (6.09)**
	Observations	**76993**	**75893**	**73030**	**73030**	**73030**
	R-squared	**0.06**	**0.06**	**0.13**	**0.13**	**0.13**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%					

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Constant	**3.658** (403.54)**	**4.029** (290.21)**	**3.759** (308.24)**	**2.663** (96.48)**	**3.378** (558.23)**	**3.537** (94.39)**
Policy	Transit access <400m	**-0.459** (35.48)**	**-0.297** (21.65)**				**-0.168** (10.81)**
	Transit access 400-1000m	**-0.434** (28.11)**	-0.222 (13.43)**				**-0.127** (7.24)**
	Operating Cost per km of Car Travel		**-0.073** (34.45)**				**-0.034** (7.98)**
Spatial development patterns	Population density			**-0.153** (35.90)**			**-0.057** (10.85)**
	Mix of use			**-0.388** (13.82)**			**-0.358** (12.63)**
Socioeconomic and demographic variables	Household Income				**0.003** (14.36)**		**0.003** (12.02)**
	Car access/availability				**0.362** (26.99)**		**0.14** (10.24)**
	Driver's License				**0.313** (14.11)**		**0.269** (11.63)**
	Younger than 16/18				**-0.359** (14.36)**		**-0.463** (18.08)**
	Single HH with Job				**0.006** -0.24		**0.024** (0.99)
	Single HH without Job				**-0.156** (2.24)*		**-0.115** -1.5
	Couple HH with Job				**0.084** (5.30)**		**0.025** (1.59)
	Couple HH without Job				**-0.303** (11.75)**		**-0.229** (8.95)**
	HH, Small Children with Job				**0.106** (5.72)**		**0.042** (2.33)*
	HH, Small Children without Job				**-0.12** (4.12)**		**-0.128** (4.44)**
	HH, Older Children without Job				**-0.216** (8.97)**		**-0.208** (8.72)**
	Retired HH				**-0.139** (8.69)**		**-0.145** (9.13)**
	Sex (Male=1)				**0.105** (13.05)**		**0.134** (16.45)**
Macro-economic differences	Sunday					**0.092** (4.69)**	**0.092** (4.57)**
	Germany(1/0)						**-0.165** (6.09)**
	Observations	**79996**	**76993**	**79011**	**77064**	**80227**	**73030**
	R-squared	**0.03**	**0.06**	**0.04**	**0.08**	**0.00**	**0.13**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%						

Appendix Table 9.3 Dependent Variable: Daily Car Travel Distance per Person in km; Including Non-Trip Makers (Sequential and block approach)

		Model 1	***Model 2***	***Model 3***	***Model 4***	***Model 5***
	Constant	**65.1** (138.76)**	**68.338** (126.00)**	**49.306** (46.62)**	**49.24** (46.65)**	**45.722** (43.17)**
Policy	Transit access <400m	**-11.821** (27.21)**	**-7.563** (16.10)**	**-6.807** (14.47)**	**-6.808** (14.47)**	**-5.945** (12.60)**
	Transit access 400-1000m	**-9.304** (18.57)**	-6.507 (12.63)**	-6.005 (11.66)**	-6.003 (11.66)**	-4.592 (8.77)**
	Operating Cost per km of Car Travel	**-3.134** (51.30)**	**-2.738** (42.54)**	**-2.278** (33.25)**	**-2.277** (33.25)**	**-0.878** (7.79)**
Spatial developme nt patterns	Population density		**-2.699** (19.36)**	**-2.499** (17.57)**	**-2.499** (17.58)**	**-2.244** (15.81)**
	Mix of use		**-11.177** (12.61)**	**-11.286** (12.67)**	**-11.287** (12.67)**	**-11.527** (12.96)**
Socioeconomic and demographic variables	Household Income			**0.083** (11.15)**	**0.083** (11.16)**	**0.074** (9.92)**
	Car access/availability			**5.736** (12.74)**	**5.735** (12.74)**	**4.67** (10.31)**
	Driver's License			**10.59** (20.62)**	**10.593** (20.64)**	**10.691** (20.98)**
	Younger than 16/18			**-11.834** (19.24)**	**-11.83** (19.24)**	**-12.03** (19.67)**
	Single HH with Job			**1.573** (1.80)	**1.573** -1.8	**1.177** -1.35
	Single HH without Job			**-3.889** -1.77	**-3.896** -1.77	**-4.426** (2.01)*
	Couple HH with Job			**0.774** -1.41	**0.774** -1.41	**0.378** -0.69
	Couple HH without Job			**-7.35** (10.66)**	**-7.356** (10.67)**	**-7.108** (10.35)**
	HH, Small Children with Job			**2.897** (4.39)**	**2.898** (4.39)**	**2.386** (3.62)**
	HH, Small Children without Job			**-3.815** (4.30)**	**-3.816** (4.30)**	**-4.06** (4.61)**
	HH, Older Children without Job			**-5.918** (8.31)**	**-5.92** (8.31)**	**-5.964** (8.40)**
	Retired HH			**-4.899** (9.81)**	**-4.899** (9.81)**	**-5.398** (10.77)**
	Sex (Male=1)			**3.243** (13.61)**	**3.24** (13.61)**	**3.159** (13.27)**
Macro-economic differences	Sunday				**0.436** (0.71)	**0.372** (0.61)
	Germany(1/0)					**-11.085** (15.00)**
	Observations	**87399**	**86144**	**83048**	**83048**	**83048**
	R-squared	**0.09**	**0.10**	**0.17**	**0.17**	**0.17**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%					

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Constant	**65.1** (138.76)**	**44.355** (119.80)**	**5.343** (10.16)**	**30.717** (189.14)**	**40.562** (166.13)**	**45.722** (43.17)**
Policy	Transit access <400m	**-11.821** (27.21)**					**-5.945** (12.60)**
	Transit access 400-1000m	**-9.304** (18.57)**					**-4.592** (8.77)**
	Operating Cost per km of Car Travel	**-3.134** (51.30)**					**-0.878** (7.79)**
Spatial development patterns	Population density		**-5.682** (53.22)**				**-2.244** (15.81)**
	Mix of use		**-11.014** (13.67)**				**-11.527** (12.96)**
Socioeconomic and demographic variables	Household Income			**0.109** (15.94)**			**0.074** (9.92)**
	Car access/availability			**14.732** (37.09)**			**4.67** (10.31)**
	Driver's License			**12.872** (36.95)**			**10.691** (20.98)**
	Younger than 16/18			**-6.953** (14.21)**			**-12.03** (19.67)**
	Single HH with Job			**-0.536** (0.70)			**1.177** (1.35)
	Single HH without Job			**-9.702** (7.79)**			**-4.426** (2.01)*
	Couple HH with Job			**2.283** (4.29)**			**0.378** (0.69)
	Couple HH without Job			**-11.442** (19.17)**			**-7.108** (10.35)**
	HH, Small Children with Job			**5.12** (7.92)**			**2.386** (3.62)**
	HH, Small Children without Job			**-5.596** (7.21)**			**-4.06** (4.61)**
	HH, Older Children without Job			**-7.516** (11.92)**			**-5.964** (8.40)**
	Retired HH			**-6.853** (15.14)**			**-5.398** (10.77)**
	Sex (Male=1)			**2.075** (9.89)**			**3.159** (13.27)**
Macro-economic differences	Sunday				**-2.368** (4.62)**		**0.372** (0.61)
	Germany(1/0)					**-21.289** (71.28)**	**-11.085** (15.00)**
	Observations	**87399**	**107501**	**105117**	**109640**	**109640**	**83048**
	R-squared	**0.09**	**0.05**	**0.12**	**0.00**	**0.07**	**0.17**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%						

Appendix Table 9.4 Dependent Variable: Daily Car Travel Distance per Person in km; Groups of Independent Variables Approach (Block Approach) with Interaction

		Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
Policy	Transit access <400m	**-11.643** (19.73)**					**-6.815** (9.36)**
	Transit access <400m G	**7.783** (7.71)**					**4.748** (4.35)**
	Transit access 400-1000m	**-8.252** (9.55)**					**-5.689** (6.19)**
	Transit access 400-1000m G	**5.607** (4.65)**					**3.81** (3.08)**
	Operating cost per km of car travel	**-2.733** (11.31)**					**-2.757** (11.02)**
	Operating cost per km of car travel G	**2.077** (6.76)**					**2.515** (8.04)**
Spatial development patterns	Population density		**-4.018** (19.24)**				**-2.656** (10.29)**
	Population density G		**2.368** (7.80)**				**0.922** (2.70)**
	Mix of use		**-14.465** (12.71)**				**-13.217** (11.25)**
	Mix of use G		**0.444** (0.21)				**0.385** (0.18)
Socioeconomic and demographic variables	Household income			**0.048** (5.28)**			**0.06** (6.62)**
	Household income G			**0.033** -1.81			**0.04** (2.21)*
	Car access/availability			**4.908** (8.67)**			**3.095** (5.51)**
	Car access/availability G			**3.34** (3.20)**			**3.455** (3.40)**
	Driver's License			**8.076** (7.93)**			**6.599** (6.47)**
	Driver's License G			**-2.633** -1.95			**-1.258** -0.93
	Younger than 16/18			**-15.003** (13.58)**			**-16.08** (14.53)**
	Younger than 16/18 G			**5.756** (3.74)**			**6.683** (4.35)**
	Sex (Male=1)			**3.173** (8.15)**			**3.765** (9.59)**
	Sex (Male=1) G			**1.552** (2.93)**			**1.042** -1.96

Socioeconomic and demographic variables	Single HH with job			**-5.278** (4.52)**			**-2.619** (2.22)*
	Single HH with job G			**8.202** (4.38)**			**7.428** (3.97)**
	Single HH without job			**-12.349** (3.40)**			**-9.82** (2.72)**
	Single HH without job G			**12.805** (2.54)*			**12.005** (2.44)*
	Couple HH with job			**-1.903** (2.32)*			**-1.171** -1.43
	Couple HH with job G			**3.778** (3.26)**			**2.753** (2.40)*
	Couple HH without job			**-6.247** (3.51)**			**-5.689** (3.22)**
	Couple HH without job G			**2.088** (1.05)			**1.734** (0.88)
	HH, small children with job			**1.862** (1.91)			**2.383** (2.48)*
	HH, small children with job G			**-2.056** (1.50)			**-1.897** (1.39)
	HH, small children without job			**-5.654** (3.74)**			**-4.652** (3.07)**
	HH, small children without job G			**2.619** -1.35			**2.388** -1.23
	HH, older children without job			**-6.503** (4.82)**			**-6.536** (4.85)**
	HH, older children without job G			**3.261** (1.97)*			**2.793** -1.7
	Retired HH			**-9.652** (11.23)**			**-9.187** (10.72)**
	Retired HH G			**7.61** (6.83)**			**7.894** (7.12)**
Macro-economic differences	Sunday				**-1.157** (1.28)		**-0.926** (0.99)
	Sunday G				**4.41** (3.30)**		**5.175** (3.78)**
	Germany(1/0)	**-24.021** (11.91)**	**-18.191** (20.61)**	**-23.067** (12.40)**	**-18.601** (47.94)**	**-18.086** (48.34)**	**-33.077** (11.99)**
	Constant	**67.551** (61.76)**	**60.069** (110.99)**	**41.484** (30.58)**	**51.515** (178.28)**	**51.357** (186.31)**	**65.071** (36.82)**
	Observations	**72605**	**71782**	**70057**	**72827**	**72827**	**69302**
	R-squared	**0.06**	**0.06**	**0.09**	**0.05**	**0.05**	**0.11**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%						

Appendix Table 9.5 Dependent Variable: LN(Daily Car Travel Distance per Person in km); (Sequential and block approach) with Interaction

		Model 1	Model 2	Model 3	Model 4	Model 5
Policy	Transit access <400m		**-0.316** (18.80)**	**-0.164** (7.98)**	**-0.161** (7.68)**	**-0.161** (7.69)**
	Transit access <400m G		**0.168** (5.22)**	**0.052** (1.51)	**0.058** (1.68)	**0.057** (1.68)
	Transit access 400-1000m		**-0.185** (7.62)**	**-0.1** (3.99)**	**-0.105** (4.07)**	**-0.105** (4.08)**
	Transit access 400-1000m G		**0.089** (2.37)*	**0.018** (0.46)	**0.022** (0.59)	**0.024** (0.62)
	Operating cost per km of car travel		**-0.076** (10.76)**	**-0.078** (11.00)**	**-0.078** (10.70)**	**-0.078** (10.69)**
	Operating cost per km of car travel G		**0.062** (6.62)**	**0.068** (7.26)**	**0.069** (7.29)**	**0.069** (7.34)**
Spatial development patterns	Population density			**-0.085** (11.53)**	**-0.081** (10.47)**	**-0.081** (10.49)**
	Population density G			**0.07** (6.46)**	**0.059** (5.30)**	**0.057** (5.17)**
	Mix of use			**-0.38** (11.73)**	**-0.38** (11.54)**	**-0.38** (11.55)**
	Mix of use G			**-0.115** (1.59)	**-0.079** (1.10)	**-0.078** (1.09)
Socioeconomic and demographic variables	Household income				**0.002** (9.70)**	**0.002** (9.71)**
	Household income G				**0.001** (2.27)*	**0.001** (2.27)*
	Car access/availability				**0.113** (7.33)**	**0.113** (7.34)**
	Car access/availability G				**0.149** (4.35)**	**0.15** (4.39)**
	Driver's License				**0.258** (8.36)**	**0.258** (8.38)**
	Driver's License G				**-0.009** (0.19)	**-0.001** (0.03)
	Younger than 16/18				**-0.486** (15.29)**	**-0.486** (15.29)**
	Younger than 16/18 G				**0.022** (0.41)	**0.027** (0.50)
	Sex (Male=1)				**0.117** (11.08)**	**0.117** (11.08)**
	Sex (Male=1) G				**0.055** (3.31)**	**0.053** (3.23)**

Socioeconomic and demographic variables	Single HH with job				**-0.056** (1.95)	**-0.056** (1.95)
	Single HH with job G				**0.221** (4.18)**	**0.222** (4.20)**
	Single HH without job				**-0.249** (2.45)*	**-0.25** (2.46)*
	Single HH without job G				**0.3** (1.92)	**0.294** (1.89)
	Couple HH with job				**0.01** (0.49)	**0.01** (0.49)
	Couple HH with job G				**0.035** (1.07)	**0.036** (1.11)
	Couple HH without job				**-0.224** (4.94)**	**-0.224** (4.95)**
	Couple HH without job G				**0.018** (0.33)	**0.018** (0.33)
	HH, small children with job				**0.049** (2.20)*	**0.049** (2.19)*
	HH, small children with job G				**-0.045** (1.19)	**-0.044** (1.15)
	HH, small children without job				**-0.151** (3.70)**	**-0.151** (3.70)**
	HH, small children without job G				**0.062** (1.07)	**0.063** (1.11)
	HH, older children without job				**-0.225** (6.44)**	**-0.225** (6.44)**
	HH, older children without job G				**0.042** (0.88)	**0.039** (0.83)
	Retired HH				**-0.209** (9.65)**	**-0.209** (9.65)**
	Retired HH G				**0.132** (4.14)**	**0.133** (4.19)**
Macro-economic differences	Sunday					**0.022** (0.86)
	Sunday G					**0.183** (4.41)**
	Germany(1/0)	**-0.55** (47.86)**	**-0.715** (11.22)**	**-0.738** (11.13)**	**-0.948** (10.59)**	**-0.977** (10.91)**
	Constant	**3.607** (483.62)**	**4.064** (129.47)**	**4.224** (127.99)**	**3.855** (77.15)**	**3.851** (76.94)**
	Observations	**80227**	**76993**	**75893**	**73030**	**73030**
	R-squared	**0.05**	**0.06**	**0.07**	**0.13**	**0.13**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%					

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Policy	Transit access <400m	**-0.329** (19.84)**	**-0.316** (18.80)**				**-0.161** (7.69)**
	Transit access <400m G	**0.175** (5.46)**	**0.168** (5.22)**				**0.057** -1.68
	Transit access 400-1000m	**-0.179** (7.43)**	**-0.185** (7.62)**				**-0.105** (4.08)**
	Transit access 400-1000m G	**0.08** (2.17)*	**0.089** (2.37)*				**0.024** -0.62
	Operating cost per km of car travel		**-0.076** (10.76)**				**-0.078** (10.69)**
	Operating cost per km of car travel G		**0.062** (6.62)**				**0.069** (7.34)**
Spatial development patterns	Population density			**-0.117** (18.76)**			**-0.081** (10.49)**
	Population density G			**0.094** (9.44)**			**0.057** (5.17)**
	Mix of use			**-0.417** (13.17)**			**-0.38** (11.55)**
	Mix of use G			**-0.088** (1.23)			**-0.078** (1.09)
Socioeconomic and demographic variables	Household income				**0.002** (9.43)**		**0.002** (9.71)**
	Household income G				**0.001** (1.86)		**0.001** (2.27)*
	Car access/availability				**0.168** (11.38)**		**0.113** (7.34)**
	Car access/availability G				**0.144** (4.32)**		**0.15** (4.39)**
	Driver's License				**0.355** (12.22)**		**0.258** (8.38)**
	Driver's License G				**-0.103** (2.27)*		**-0.001** (0.03)
	Younger than 16/18				**-0.403** (13.13)**		**-0.486** (15.29)**
	Younger than 16/18 G				**-0.053** (1.01)		**0.027** (0.50)
	Sex (Male=1)				**0.1** (9.68)**		**0.117** (11.08)**
	Sex (Male=1) G				**0.069** (4.27)**		**0.053** (3.23)**

Socioeconomic and demographic variables	Single HH with job				**-0.136** (4.81)**		**-0.056** (1.95)
	Single HH with job G				**0.242** (4.72)**		**0.222** (4.20)**
	Single HH without job				**-0.365** (3.96)**		**-0.25** (2.46)*
	Single HH without job G				**0.35** (2.48)*		**0.294** (1.89)
	Couple HH with job				**-0.008** -0.4		**0.01** -0.49
	Couple HH with job G				**0.056** (1.73)		**0.036** (1.11)
	Couple HH without job				**-0.206** (4.52)**		**-0.224** (4.95)**
	Couple HH without job G				**-0.008** (0.14)		**0.018** (0.33)
	HH, small children with job				**0.029** (1.27)		**0.049** (2.19)*
	HH, small children with job G				**-0.034** (0.88)		**-0.044** (1.15)
	HH, small children without job				**-0.17** (4.24)**		**-0.151** (3.70)**
	HH, small children without job G				**0.077** (1.36)		**0.063** (1.11)
	HH, older children without job				**-0.225** (6.58)**		**-0.225** (6.44)**
	HH, older children without job G				**0.053** (1.13)		**0.039** (0.83)
	Retired HH				**-0.221** (10.35)**		**-0.209** (9.65)**
	Retired HH G				**0.119** (3.78)**		**0.133** (4.19)**
Macro-economic differences	Sunday					**0.004** (0.17)	**0.022** (0.86)
	Sunday G					**0.165** (4.10)**	**0.183** (4.41)**
	Germany(1/0)	**-0.557** (21.34)**	**-0.715** (11.22)**	**-0.585** (21.31)**	**-0.639** (10.80)**	**-0.569** (47.49)**	**-0.977** (10.91)**
	Constant	**3.728** (386.13)**	**4.064** (129.47)**	**3.862** (271.68)**	**3.121** (84.80)**	**3.606** (459.53)**	**3.851** (76.94)**
	Observations	**79996**	**76993**	**79011**	**77064**	**80227**	**73030**
	R-squared	**0.05**	**0.06**	**0.06**	**0.11**	**0.05**	**0.13**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%						

Appendix Table 9. 6 Dependent Variable: Daily Car Travel Distance per Person in km; Including Non-Trip Makers (Sequential and block approach) with Interaction

		Model 1	***Model 2***	***Model 3***	***Model 4***	***Model 5***
Policy	Transit access <400m		**-11.68** (20.23)**	**-6.508** (9.36)**	**-6.524** (9.26)**	**-6.524** (9.26)**
	Transit access <400m G		**5.956** (6.64)**	**2.484** (2.53)*	**3.309** (3.38)**	**3.309** (3.38)**
	Transit access 400-1000m		**-7.929** (9.30)**	**-5.197** (5.94)**	**-5.271** (5.88)**	**-5.271** (5.88)**
	Transit access 400-1000m G		**4.671** (4.21)**	**2.76** (2.45)*	**2.995** (2.64)**	**3** (2.65)**
	Operating cost per km of car travel		**-2.462** (10.36)**	**-2.52** (10.62)**	**-2.399** (9.85)**	**-2.399** (9.85)**
	Operating cost per km of car travel G		**1.912** (6.67)**	**2.152** (7.52)**	**2.084** (7.15)**	**2.084** (7.16)**
Spatial development patterns	Population density			**-2.864** (12.14)**	**-2.728** (11.15)**	**-2.729** (11.16)**
	Population density G			**1.132** (3.88)**	**0.954** (3.20)**	**0.952** (3.19)**
	Mix of use			**-12.618** (11.23)**	**-12.762** (11.20)**	**-12.762** (11.20)**
	Mix of use G			**0.675** (0.37)	**2.053** (1.14)	**2.061** (1.15)
Socioeconomic and demographic variables	Household income				**0.066** (7.48)**	**0.066** (7.48)**
	Household income G				**0.022** (1.40)	**0.022** (1.40)
	Car access/availability				**3.006** (5.44)**	**3.006** (5.44)**
	Car access/availability G				**7.066** (7.76)**	**7.062** (7.76)**
	Driver's License				**11.029** (11.52)**	**11.03** (11.53)**
	Driver's License G				**-0.704** (0.64)	**-0.7** (0.64)
	Younger than 16/18				**-15.874** (15.07)**	**-15.874** (15.07)**
	Younger than 16/18 G				**7.973** (6.37)**	**7.978** (6.38)**
	Sex (Male=1)				**3.147** (8.25)**	**3.147** (8.25)**
	Sex (Male=1) G				**0.558** (1.17)	**0.554** (1.16)

Socioeconomic and demographic variables	Single HH with job				**-1.74** (1.49)	**-1.74** (1.49)
	Single HH with job G				**5.281** (2.99)**	**5.283** (2.99)**
	Single HH without job				**-8.897** (2.47)*	**-8.897** (2.47)*
	Single HH without job G				**8.018** (1.77)	**8.006** (1.77)
	Couple HH with job				**-1.263** (1.55)	**-1.263** (1.55)
	Couple HH with job G				**3.019** (2.80)**	**3.021** (2.80)**
	Couple HH without job				**-6.914** (4.04)**	**-6.915** (4.04)**
	Couple HH without job G				**1.503** (0.81)	**1.498** (0.81)
	HH, small children with job				**2.142** (2.24)*	**2.142** (2.24)*
	HH, small children with job G				**-1.768** (1.38)	**-1.768** (1.38)
	HH, small children without job				**-5.332** (3.58)**	**-5.332** (3.58)**
	HH, small children without job G				**2.249** (1.25)	**2.246** (1.25)
	HH, older children without job				**-7.686** (5.81)**	**-7.686** (5.81)**
	HH, older children without job G				**3.751** (2.45)*	**3.749** (2.44)*
	Retired HH				**-8.967** (10.59)**	**-8.967** (10.60)**
	Retired HH G				**6.782** (6.55)**	**6.779** (6.55)**
Macro-economic differences	Sunday					**0.039** (0.04)
	Sunday G					**0.524** (0.44)
	Germany(1/0)	**-24.64** (72.51)**	**-29.255** (16.70)**	**-29.119** (15.85)**	**-37.668** (15.76)**	**-37.726** (15.80)**
	Constant	**48.497** (179.16)**	**63.537** (59.04)**	**68.91** (60.43)**	**57.698** (33.92)**	**57.692** (33.96)**
	Observations	**86967**	**86731**	**85476**	**82383**	**82383**
	R-squared	**0.09**	**0.10**	**0.11**	**0.17**	**0.17**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%					

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Policy	Transit access <400m	**-11.579** (20.00)**	**-11.68** (20.23)**				**-6.524** (9.26)**
	Transit access <400m G	**5.842** (6.49)**	**5.956** (6.64)**				**3.309** (3.38)**
	Transit access 400-1000m	**-7.96** (9.34)**	**-7.929** (9.30)**				**-5.271** (5.88)**
	Transit access 400-1000m G	**4.718** (4.25)**	**4.671** (4.21)**				**3** (2.65)**
	Operating cost per km of car travel		**-2.462** (10.36)**				**-2.399** (9.85)**
	Operating cost per km of car travel G		**1.912** (6.67)**				**2.084** (7.16)**
Spatial development patterns	Population density			**-4.046** (20.34)**			**-2.729** (11.16)**
	Population density G			**2.11** (8.02)**			**0.952** (3.19)**
	Mix of use			**-13.823** (12.41)**			**-12.762** (11.20)**
	Mix of use G			**1.273** (0.71)			**2.061** (1.15)
Socioeconomic and demographic variables	Household income				**0.055** (6.18)**		**0.066** (7.48)**
	Household income G				**0.016** (1.04)		**0.022** (1.40)
	Car access/availability				**5.1** (9.16)**		**3.006** (5.44)**
	Car access/availability G				**6.86** (7.40)**		**7.062** (7.76)**
	Driver's License				**12.945** (13.59)**		**11.03** (11.53)**
	Driver's License G				**-2.252** (2.06)*		**-0.7** (0.64)
	Younger than 16/18				**-14.337** (13.62)**		**-15.874** (15.07)**
	Younger than 16/18 G				**6.812** (5.44)**		**7.978** (6.38)**
	Sex (Male=1)				**2.689** (7.12)**		**3.147** (8.25)**
	Sex (Male=1) G				**0.921** (1.95)		**0.554** (1.16)

Socioeconomic and demographic variables	Single HH with job				**-4.329** (3.72)**		**-1.74** (1.49)
	Single HH with job G				**5.685** (3.24)**		**5.283** (2.99)**
	Single HH without job				**-11.116** (3.07)**		**-8.897** (2.47)*
	Single HH without job G				**7.285** (1.59)		**8.006** (1.77)
	Couple HH with job				**-1.985** (2.43)*		**-1.263** (1.55)
	Couple HH with job G				**3.953** (3.63)**		**3.021** (2.80)**
	Couple HH without job				**-7.483** (4.35)**		**-6.915** (4.04)**
	Couple HH without job G				**1.757** (0.94)		**1.498** (0.81)
	HH, small children with job				**1.63** (1.68)		**2.142** (2.24)*
	HH, small children with job G				**-1.508** (1.17)		**-1.768** (1.38)
	HH, small children without job				**-6.315** (4.27)**		**-5.332** (3.58)**
	HH, small children without job G				**2.883** (1.61)		**2.246** (1.25)
	HH, older children without job				**-7.52** (5.70)**		**-7.686** (5.81)**
	HH, older children without job G				**3.713** (2.42)*		**3.749** (2.44)*
	Retired HH				**-9.234** (10.87)**		**-8.967** (10.60)**
	Retired HH G				**6.311** (6.08)**		**6.779** (6.55)**
Macro-economic differences	Sunday					**0.07** (0.08)	**0.039** (0.04)
	Sunday G					**0.39** (0.33)	**0.524** (0.44)
	Germany(1/0)	**-24.967** (34.29)**	**-29.255** (16.70)**	**-24.297** (31.03)**	**-30.152** (19.11)**	**-24.685** (69.78)**	**-37.726** (15.80)**
	Constant	**52.99** (143.64)**	**63.537** (59.04)**	**57.166** (107.67)**	**34.956** (27.18)**	**48.488** (170.90)**	**57.692** (33.96)**
	Observations	**86731**	**86731**	**85706**	**83823**	**86967**	**82383**
	R-squared	**0.10**	**0.10**	**0.11**	**0.15**	**0.09**	**0.17**
	F-statistic	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at 1%						

Appendix Table 9.7 Separate Country Models to Control for Multicoliniarity and Bias

		Germany	***USA***
	Constant		
Policy	Transit access <400m	**-6.815** (9.36)**	**-2.078** (2.56)*
	Transit access 400-1000m	**-5.689** (6.19)**	**-1.998** (2.40)*
	Operating Cost per km of Car Travel	**-2.757** (11.02)**	**-0.595** (3.69)**
Spatial development patterns	Population density	-2.656 (10.29)**	**-1.702** (7.52)**
	Mix of use	-13.217 (11.25)**	**-12.935** (7.41)**
Socioeconomics and demographics	Household Income	**0.06** (6.62)**	**0.099** (6.23)**
	Car access/availability	3.095 (5.51)**	**6.679** (7.83)**
	Driver's License	6.599 (6.47)**	5.447 (6.23)**
	Younger than 16/18	-16.08 (14.54)**	**-9.351** (8.77)**
	Single HH with Job	-2.619 (2.22)*	**5.173** (3.52)**
	Single HH without Job	-9.82 (2.72)**	**2.552** -0.75
	Couple HH with Job	-1.171 -1.43	**1.717** (2.12)*
	Couple HH without Job	-5.689 (3.22)**	**-3.838** (4.18)**
	HH, Small Children with Job	2.383 (2.48)*	**0.204** -0.21
	HH, Small Children without Job	-4.652 (3.07)**	**-2.636** (2.18)*
	HH, Older Children without Job	-6.536 (4.85)**	**-3.492** (3.60)**
	Retired HH	-9.187 (10.72)**	**-1.175** -1.66
	Sex (Male=1)	3.765 (9.59)**	**4.859** (13.49)**
Macro-economic differences	Sunday	-0.926 -0.99	4.04 (4.09)**
	Germany(1/0)	65.071 (36.82)**	33.725 (15.63)**
	Observations	**40126**	**28714**
	R-squared	**0.08**	**0.05**
	F-statistic	*0.000***	*0.000***
	Robust t statistics in (), * significant at 5%, ** significant at		

Appendix Table 9.8 HSM Models with Transformed Coefficients for Stage 2

Heckman Selection Model for Mobility Choice and Daily Trip Distance									
		Germany				**USA**			
		STAGE 1 Person made a car trip (1/0)	**STAGE 2** Travel distance	**Transformed coefficients Stage 2**	**Marginal Change in Car Trip Making Probability at the Mean**	**STAGE 1** Person made a car trip (1/0)	**STAGE 2** Travel distance	**Transformed coefficients Stage 2**	**Marginal Change in Car Trip Making Probability at the Mean**
Policy	Transit access <400m	**-0.17** (4.28)**			**-5.4%**	**-0.139** (7.02)**			**-1.90%**
	Transit access 400-1000m	**-0.085** (2.64)**			**-2.7%**	**0.059** (1.85)			**0.90%**
	Operating cost per kilometer		**-0.389** (3.26)**				**-2.396** (11.95)**		
	Relative speed of car vs. other modes	**0.64** (93.69)**			**19.4%**	**1.088** (72.25)**			**10%**
Spatial development patterns	Population density		**-1.528** (8.72)**				**-3.275** (21.11)**		
	Mix of use		**-9.377** (6.88)**				**-12.118** (13.77)**		
Socioeconomic and demographic variables	HH income		**0.089** (7.35)**				**0.054** (8.12)**		
	Car access	**0.65** (22.14)**			**20.1%**	**0.471** (22.96)**			**14.10%**
	Younger than 16/18	**-0.65** (22.15)**	**-4.118** (5.95)**	**-6.17**	**-22.0%**	**-0.647** (19.01)**	**-15.64** (22.93)**	**-16.02**	**-17.20%**
	Sex (Male=1)	**0.041** (3.18)**			**0.1%**	**-0.066** (3.66)**			**-0.30%**
	Single HH with job	**-0.138** -1.78	**5.834** (4.08)**	**5.4**	**-4.5%**	**-0.332** (6.19)**	**-1.005** (0.86)	**-3.54**	**-7.80%**
	Single HH without job	**-0.271** -1.62	**5.26** (1.58)	**4.5**	**-9.2%**	**-0.648** (5.96)**	**-3.93** (1.13)	**-12.06**	**-14.90%**
	Couple HH with job	**0.001** -0.16	**1.224** (1.56)	**1.2**	**0.3%**	**-0.225** (5.56)**	**-0.451** (0.61)	**-1.3**	**-1.40%**
	Couple HH without job	**-0.214** (4.01)**	**-1.269** (1.42)	**-1.7**	**-7.1%**	**-0.304** (4.55)**	**-4.712** (2.96)**	**-8.1**	**-5.30%**
	HH, small children with job	**0.07** (1.74)	**-0.47** (0.49)	**-0.2**	**2.0%**	**-0.035** -0.7	**2.343** (2.73)**	**1.8**	**0.40%**
	HH, small children without job	**-0.002** (2.72)**	**-4.007** (3.16)**	**-3.5**	**-1.0%**	**-0.124** -1.77	**-5.803** (3.91)**	**-7.5**	**-1.40%**
	HH, older children without job	**-0.127** (1.91)	**-1.887** (1.85)	**-2.16**	**-4.1%**	**-0.2** (3.36)**	**-5.873** (4.41)**	**-8.6**	**-3.40%**
	Retired HH	**-0.113** (2.50)*	**-0.524** (0.82)	**-0.76**	**-3.6%**	**-0.105** (2.69)**	**-9.053** (12.07)**	**-11.23**	**-3.50%**
	Sunday	**-0.23** (8.13)**			**-7.9%**	**-0.067** (6.20)**			**-1.30%**
	Constant	**-2.58** (58.54)**	**50.909** (36.18)**			**-3.426** (45.92)**	**75.72** (66.90)**		
	Observations	**39951**	**39951**			**44027**	**44027**		
	Likelihood Ratio	-116242.2							
	LR Test (Chi Square(13))	**Prob > Chi Square=0.000**				**Prob > Chi Square=0.000**			
	Rho (Athrho)	**-1.05** (65.93)**				**-1.04** (85.54)**			

Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%, coefficients of variables in both models shaded in grey

Appendix Table 9.9 Simulation Results for "Car-Trip-Makers Only"

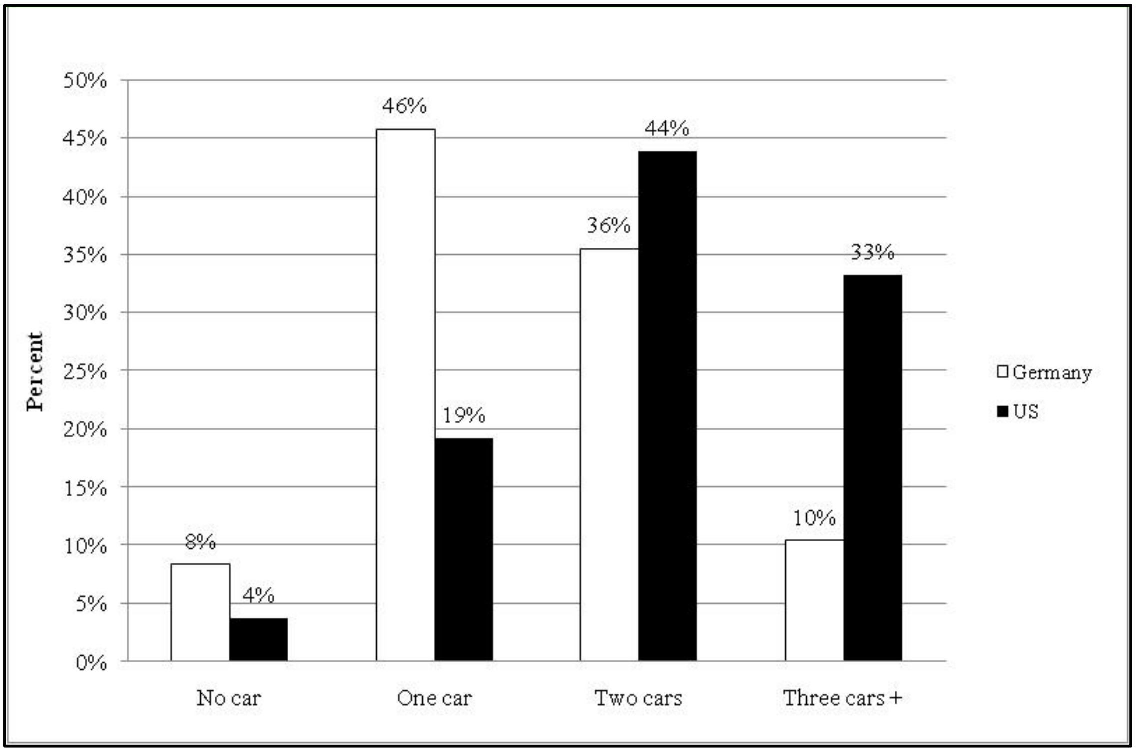
Base Case (all variables at their mean)					
	Germany		**USA**		**Difference Germany vs. USA**
All variables at averages	32.7		54.8		40%
Swapped averages (US model with German averages an vice versa)					
	Germany		**USA**		**Difference Germany vs. USA**
Swapped transport policy averages	27.2		32.8		17%
Swapped spatial development pattern averages	35.2		50.9		31%
Swapped socioeconomic and demographic variables	36.8		52		29%
Swapped averages	42.7		30.7		-39%
Effect of Individual Transport Policy Variables					
	Germany		**USA**		**Difference Germany vs. USA**
Transit farther than 1000m, other as base case	34.5		57.5		40%
Transit within 400-1000m, other as base case	32.5		51.8		37%
Transit within 400m, other as base case	31.7		50.1		37%
Operating cost=0.4, other as base case	35.3		55.6		37%
Operating cost=0.6, other as base case	34.3		50.1		32%
Operating cost=0.9, other as base case	32.9		41.8		21%
Effect of Individual Spatial Development Pattern Variables					
	Germany		**USA**		**Difference Germany vs. USA**
Density=1000, other as base case	35.1		54.9		36%
Density=2500, other as base case	32.6		50.9		36%
Density=5000, other as base case	28.3		44.3		36%
Mix of use=0.25, other as base case	33.8		55.7		39%
Mix of use=0.5, other as base case	30.5		52.4		42%
Mix of use=0.75, other as base case	27.3		49.1		44%
Effects of Individual Socioeconomic and Demographic Variables					
	Germany		**USA**		**Difference Germany vs. USA**
Cars per HH member= 0.5, other as base	31		52.8		41%
Cars per HH member= 1, other as base	34.3		54.4		37%
Cars per HH member= 1.5, other as base	37.7		55.9		33%
HH income= 10,000, other as base case	28.8		51.8		44%
HH income= 35,000, other as base case	31.2		53.3		41%
HH income= 75,000, other as base case	35.2		55.7		37%
Child/teenager=1, other as base case	26.8		46.2		42%
Female=1, other as base case	30.2		53		43%
Female=0, other as base case	35.1		56.8		38%
Retired=1, other as base case	31.8		47.3		33%
License=1, other as base case	33.8		56.3		40%
License=0, other as base case	28.4		49.7		43%

Appendix Chapter 10

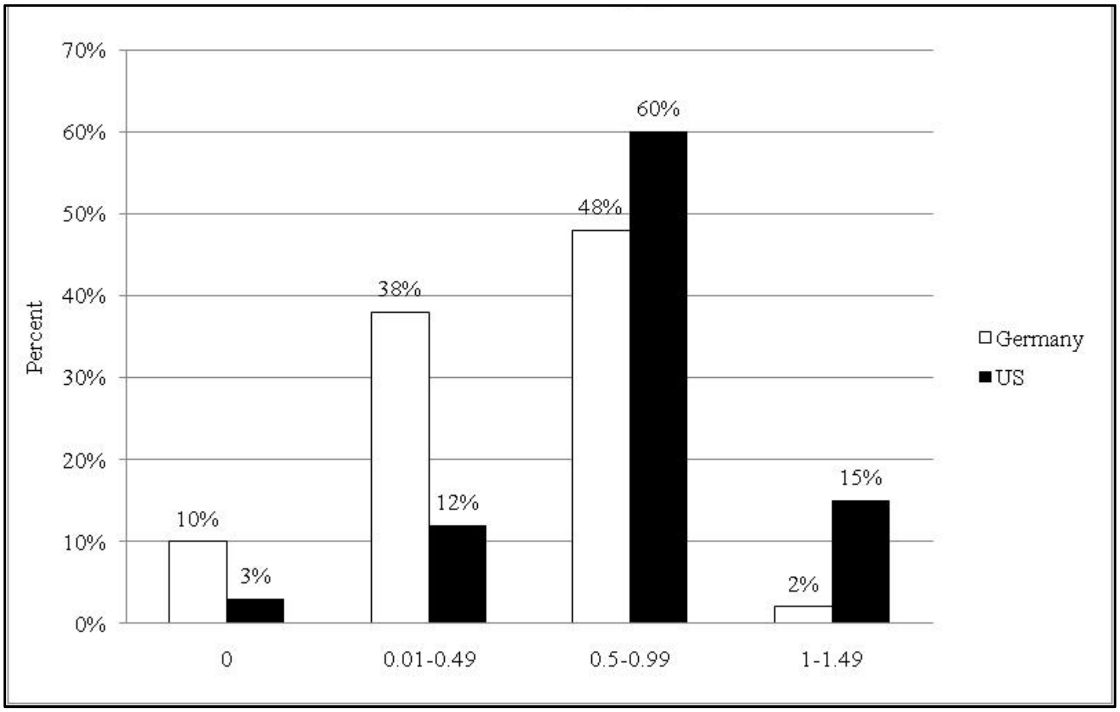
Appendix Table 10.1 Socioeconomic Characteristics of the Sample

	Germany					USA				
	Mean	Median	Std	Min	Max	Mean	Median	Std	Min	Max
Age	39.1	39.0	20.6	0.0	97.0	36.1	36.0	21.0	0.0	104.0
Age categories										
0-9	9.3%					12.0%				
10-17	9.7%					10.7%				
18-24	8.8%					9.2				
25-49	39.5%					41.5%				
50-65	19.2%					16.3%				
66-74	8.9%					6.6%				
75 plus	4.6%					3.8%				
Household Size	3.2	3.0	1.3	1.0	8.0	3.2	3.0	1.5	1.0	14.0
% male	51.4%					51.5%				
% with a job	44.1%					57.2%				
Household Income										
% with income less than 25k	19.4%					17.6%				
% with income 25k to 55k	52.2%					35.0%				
% with income 55k plus	28.0%					47.0%				
Driver's license										
% with driver's license	72.8%					90.1%				
% with driver's license at driving age	89.7%					94.8%				

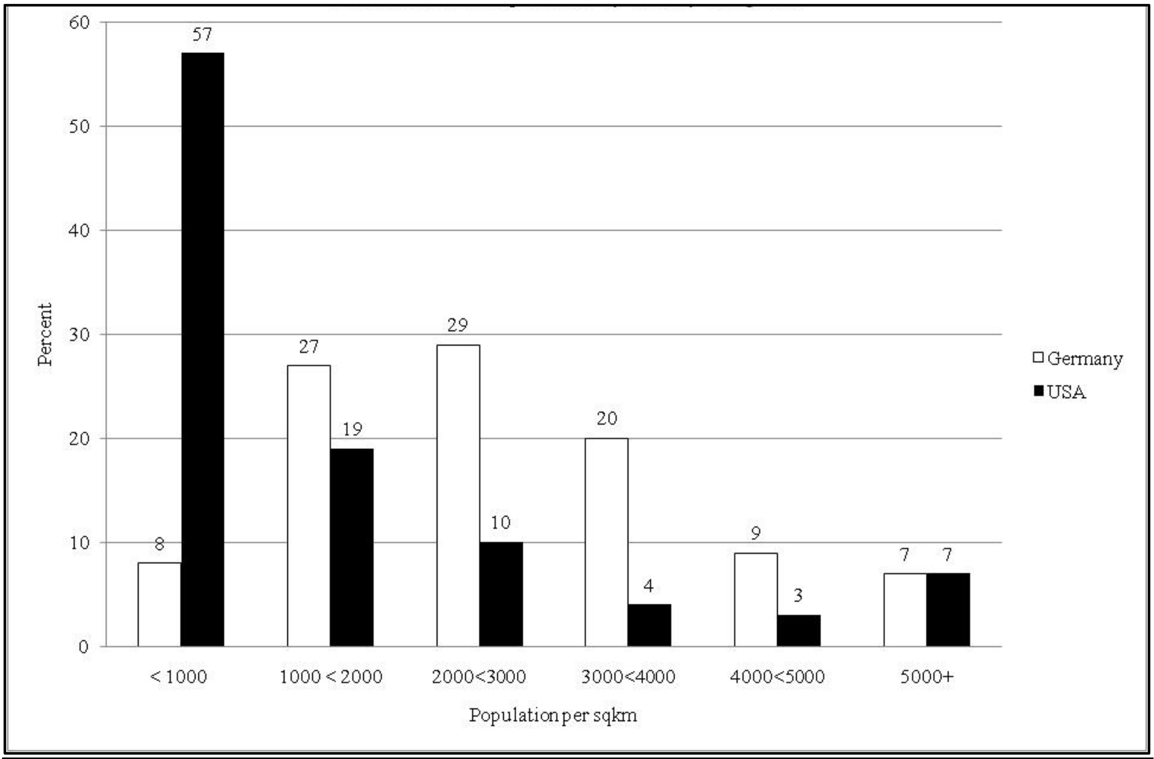
Appendix Exhibit 10.1 Percent Distribution of Trips by Number of Cars per Household



Appendix Exhibit 10.2 Percent Distribution of Trips by Number of Cars per Household Member at Driving Age



Appendix Exhibit 10.3 Percent Distribution of Trips by Population Density Category



Appendix Table 10.2 Dependent and Independent Variables for MNLM and CL

		Level of Measurement	Mean	Min	Max	N
Dependent variable						
	Mode Choice	categorical: Car, transit, bike, walk	*n.a.*	0	4	410,911
Independent variables						
Policy	Transit access <400m	nominal/dummy (1= hh within 400m of transit stop)	*n.a.*	0	1	415,166
	Transit access 400-1000m	nominal/dummy (1= hh within 400-1000m of transit stop)	*n.a.*	0	1	415,166
	Speed	interval ratio	*25.70*	0.2	105	402,498
Spatial development patterns	Population density	interval ratio	1,669	0.1	9,979	409,889
	Mix of use	interval ratio	0.33	0.01	9.99	411,126
Socioeconomic and demographic variables	Household Income	interval ratio	88	2,500	115,000	399,544
	Car access/availability	interval ratio	0.95	0	4	415,032
	Driver's license	nominal/dummy (1=respondent has driver's license)	*n.a.*	0	1	353,848
	Younger than 16/18	nominal/dummy (1=respondent younger than driving age)	*n.a.*	0	1	414,908
	Employed in single HH	nominal/dummy (1=respondent with job in single HH)	*n.a.*	0	1	414,909
	Unemployed in single HH	nominal/dummy (1=respondent without job in single HH)	*n.a.*	0	1	414,910
	Employed in adult only HH	nominal/dummy (1=respondent with job in 2 pers. HH)	*n.a.*	0	1	414,911
	Unemployed in adult only HH	nominal/dummy (1=respondent without job in 2 pers. HH)	*n.a.*	0	1	414,912
	Employed in HH with small children	nominal/dummy (1=respondent with job in HH with child 0-5)	*n.a.*	0	1	414,913
	Unemployed in HH with small children	nominal/dummy (1=respondent without job in HH with child 0-5)	*n.a.*	0	1	414,914
	Unemployed in HH with school children	nominal/dummy (1=respondent without job in HH with child 6-16/18)	*n.a.*	0	1	414,915
	Retired HH	nominal/dummy (1=respondent retired in retired HH)	*n.a.*	0	1	414,916
	Sex (Male=1)	nominal/dummy (1=male)	*n.a.*	0	1	415,166
Trip Purpose	Work trip	nominal/dummy (1=work trip)	*n.a.*	0	1	343,974
	Shopping trip	nominal/dummy (1=shopping trip)	*n.a.*	0	1	343,974
	Germany(1/0)	nominal/dummy (1=Respondent from	*n.a.*	0	1	417,074

Appendix Table 10.3 Sequentially Adding Groups of Independent Variables to the MNLM

		transit	bike	walk	transit	bike	walk	transit	bike	walk	transit	bike	walk
Policy	Transit access <400m	**0.572**	**0.183**	**0.699**	**0.01**	**-0.006**	**0.231**	**0.026**	**0.075**	**0.204**	**0.044**	**0.082**	**0.194**
		(15.07)**	(2.32)*	(27.47)**	(0.21)	(0.06)	(7.52)**	(0.50)	(0.76)	(6.39)**	(0.83)	(0.82)	(5.87)**
	Transit access <400m G	**0.427**	**-0.02**	**0.031**	**0.703**	**0.131**	**0.385**	**0.55**	**-0.023**	**0.327**	**0.514**	**-0.039**	**0.307**
		(6.22)**	(0.22)	(0.73)	(9.33)**	(1.22)	(8.30)**	(6.93)**	(0.21)	(6.81)**	(6.33)**	(0.35)	(6.22)**
	Transit access 400-1000m	**-0.088**	**-0.035**	**0.181**	**-0.264**	**-0.119**	**0.006**	**-0.195**	**-0.084**	**0.005**	**-0.193**	**-0.106**	**0.003**
		(1.36)	(0.31)	(4.60)**	(3.93)**	(1.00)	(0.15)	(2.78)**	(0.69)	(0.11)	(2.72)**	(0.85)	(0.07)
	Transit access 400-1000m G	**0.595**	**0.079**	**0.244**	**0.614**	**0.139**	**0.352**	**0.502**	**0.095**	**0.339**	**0.503**	**0.114**	**0.299**
		(6.74)**	(0.64)	(4.59)**	(6.75)**	(1.07)	(6.51)**	(5.32)**	(0.72)	(6.08)**	(5.27)**	(0.85)	(5.23)**
	Germany(1/0)	**0.851**	**2.905**	**1.222**	**-0.177**	**2.726**	**0.982**	**1.522**	**4.558**	**1.817**	**1.322**	**3.907**	**1.512**
		(14.30)**	(46.13)**	(33.91)**	(2.28)*	(30.38)**	(21.32)**	(10.47)**	(21.48)**	(22.19)**	(8.79)**	(18.40)**	(17.70)**
Spatial development patterns	Population density				**0.174**	**0.083**	**0.178**	**0.144**	**0.081**	**0.149**	**0.149**	**0.085**	**0.156**
					(12.02)**	(2.64)**	(21.24)**	(8.79)**	(2.49)*	(16.84)**	(8.88)**	(2.52)*	(16.69)**
	Population density G				**0.233**	**-0.07**	**-0.038**	**0.238**	**-0.096**	**-0.025**	**0.243**	**-0.097**	**-0.04**
					(12.20)**	(2.06)*	(3.15)**	(11.50)**	(2.73)**	(2.03)*	(11.46)**	(2.69)**	(3.06)**
	Mix of use				**-0.231**	**0.072**	**0.302**	**-0.151**	**0.166**	**0.307**	**-0.133**	**0.137**	**0.282**
					(2.70)**	(0.45)	(6.03)**	(1.66)	(1.02)	(5.92)**	(1.45)	(0.85)	(5.24)**
	Mix of use G				**0.6**	**0.584**	**0.131**	**0.26**	**0.283**	**-0.032**	**0.292**	**0.346**	**0.03**
					(4.33)**	(3.12)**	(1.53)	(1.79)	(1.48)	-0.37	(1.98)*	(1.81)	(0.33)
Socioeconomic and demographic variables	Car access/availability							**-0.664**	**-0.242**	**-0.543**	**-0.783**	**-0.304**	**-0.578**
								(9.44)**	(2.47)*	(13.62)**	(11.16)**	(3.13)**	(14.02)**
	Car access/availability G							**-1.517**	**-1.421**	**-0.724**	**-1.452**	**-1.391**	**-0.699**
								(15.96)**	(12.54)**	(12.63)**	(15.11)**	(12.28)**	(11.73)**
	Household income							**-0.004**	**-0.002**	**-0.001**	**-0.005**	**-0.002**	**-0.001**
								(6.65)**	(1.82)	(0.57)	(7.49)**	(2.00)*	(1.28)
	Household income G							**0.003**	**0.003**	**-0.008**	**0.003**	**0.003**	**-0.006**
								(2.82)**	(1.97)*	(9.60)**	(2.15)*	(1.89)	(7.90)**
	Sex (Male=1)							**0.079**	**0.737**	**-0.012**	**0.041**	**0.723**	**-0.014**
								(1.94)	(9.28)**	-0.46	(1.00)	(9.06)**	(0.53)
	Sex (Male=1) G							**-0.455**	**-0.743**	**-0.243**	**-0.463**	**-0.729**	**-0.23**
								(8.83)**	(8.74)**	(7.46)**	(8.85)**	(8.53)**	(6.84)**

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Socioeconomic and demographic variables	Single HH with job							**0.61**	**0.463**	**0.524**	**0.569**	**0.386**	**0.459**
								(4.34)**	(1.81)	(8.21)**	(4.02)**	(1.52)	(6.93)**
	Single HH with job G							**0.11**	**0.017**	**-0.159**	**0.057**	**0.068**	**-0.066**
								(0.65)	(0.06)	(1.74)	(0.34)	(0.25)	(0.70)
	Single HH without job							**1.032**	**1.109**	**1.135**	**1.192**	**0.797**	**0.828**
								(3.78)**	(2.47)*	(8.53)**	(4.30)**	(1.76)	(6.05)**
	Single HH without job G							**-0.018**	**-0.053**	**-0.516**	**-0.094**	**0.198**	**-0.429**
								(0.06)	(0.11)	(2.98)**	(0.30)	(0.41)	(2.43)*
	Couple HH with job							**0.337**	**0.308**	**0.247**	**0.274**	**0.252**	**0.207**
								(3.30)**	(1.89)	(5.92)**	(2.66)**	(1.54)	(4.83)**
	Couple HH with job G							**-0.358**	**-0.403**	**-0.196**	**-0.363**	**-0.366**	**-0.134**
								(2.95)**	(2.31)*	(3.35)**	(2.97)**	(2.08)*	(2.24)*
	Couple HH without job							**0.887**	**0.348**	**0.554**	**1.193**	**0.104**	**0.305**
								(5.05)**	(0.72)	(6.75)**	(6.60)**	(0.22)	(3.60)**
	Couple HH without job G							**-0.738**	**0.106**	**-0.062**	**-0.762**	**0.392**	**-0.019**
								(3.91)**	(0.22)	(0.67)	(3.91)**	(0.81)	(0.20)
	HH, children without job							**0.283**	**-0.021**	**0.375**	**0.679**	**-0.164**	**0.154**
								-1.95	(0.08)	(6.62)**	(4.32)**	(0.58)	(2.55)*
	HH, children without job G							**-0.132**	**0.208**	**-0.087**	**-0.168**	**0.376**	**-0.109**
								(0.83)	(0.75)	(1.25)	(0.98)	(1.30)	(1.47)
	Retired HH							**-0.398**	**0.132**	**0.368**	**-0.156**	**-0.114**	**0.117**
								(2.98)**	(0.89)	(9.05)**	(1.14)	(0.76)	(2.77)**
	Retired HH G							**0.465**	**0.039**	**0.091**	**0.392**	**0.297**	**0.199**
								(3.29)**	(0.25)	(1.84)	(2.71)**	(1.90)	(3.88)**
	Younger than 16/18							**2.633**	**2.038**	**0.944**	**2.884**	**1.69**	**0.575**
								(38.34)**	(19.50)**	(26.65)**	(38.49)**	(15.42)**	(15.46)**
	Younger than 16/18 G							**-0.831**	**-0.69**	**0.37**	**-0.666**	**-0.154**	**0.558**
								(10.25)**	(6.13)**	(7.95)**	(7.45)**	(1.30)	(11.25)**
Trip Purpose	Work trip										**0.397**	**-1.197**	**-1.255**
											(6.00)**	(7.68)**	(30.04)**
	Work trip G										**0.216**	**1.216**	**0.126**
											(2.84)**	(7.60)**	(2.33)*
	Shopping trip										**-1.915**	**-1.514**	**-1.225**
											(19.03)**	(10.75)**	(33.83)**
	Shopping trip G										**1.261**	**1.326**	**0.958**
											(11.64)**	(9.19)**	(22.79)**
	Constant	**-3.654**	**-4.8**	**-2.706**	**-3.672**	**-4.855**	**-2.889**	**-3.979**	**-5.788**	**-2.658**	**-3.763**	**-5.022**	**-1.968**
		(145.79)**	(102.61)**	(157.79)**	(95.36)**	(67.54)**	(114.57)**	(35.94)**	(29.84)**	(45.47)**	(32.99)**	(26.01)**	(32.46)**
Observations		**408706**	**408706**	**408706**	**401247**	**401247**	**401247**	**385138**	**385138**	**385138**	**343974**	**343974**	**343974**
McFadden R-Square		**9.6**			**10.2**			**15.7**			**18.9**		
Log Likelihood Intercept		**-310340.98**			**-302311.04**			**-292175.57**			**-271541.78**		
Log Likelihood Full		**-282292.01**			**-271408**			**-246444.31**			**-223580.78**		
Probability> Chi Square		**0.000**			**0.000**			**0.000**			**0.000**		
Base outcome= car													
Absolute value of z statistics in parentheses													
* significant at 5%; ** significant at 1%													

Appendix Table 10.4 Mode Choice by Trip Distance in Germany

		Germany / Mode of Transport All Trips as in Chapter 10			Germany / Mode of Transport Trips < 1.6km		Germany / Mode of Transport Trips >16km
		Transit	**Bike**	**Walk**	**Bike**	**Walk**	**Transit**
	Constant	**-2.441**	**-1.116**	**-0.456**	**-0.014**	**0.444**	**-1.383**
		(24.90)**	(12.64)**	(7.57)**	(0.10)	(4.19)**	(7.47)**
Policy	Transit access <400m	**0.558**	**0.043**	**0.501**	**0.075**	**0.475**	**0.016**
		(9.08)**	(0.86)	(13.59)**	(0.88)	(7.14)**	(0.15)
	Transit access 400-1000m	**0.31**	**0.008**	**0.301**	**0.048**	**0.277**	**-0.083**
		(4.84)**	(0.15)	(7.91)**	(0.56)	(4.06)**	(0.76)
Spatial developme nt pattern	Population density	**0.392**	**-0.013**	**0.116**	**-0.023**	**0.203**	**0.294**
		(30.23)**	(0.93)	(12.79)**	(0.99)	(11.86)**	(10.86)**
	Mix of use	**0.159**	**0.483**	**0.311**	**-0.075**	**0.174**	**-1.03**
		(1.38)	(4.66)**	(4.20)**	(0.43)	(1.30)	(4.30)**
Trip Purpose	Work trip	**0.613**	**0.02**	**-1.13**	**0.701**	**-0.123**	**0.864**
		(16.19)**	(0.53)	(33.06)**	(9.88)**	(2.04)*	(11.64)**
	Shopping trip	**-0.654**	**-0.188**	**-0.266**	**-0.114**	**-0.37**	**-0.739**
		(16.31)**	(5.92)**	(12.42)**	(2.23)*	(9.84)**	(5.80)**
Socioeconomic and demographic variables	Car access/availability	**-2.236**	**-1.696**	**-1.277**	**-1.366**	**-1.059**	**-2.464**
		(34.06)**	(29.26)**	(29.71)**	(15.72)**	(15.71)**	(16.74)**
	Household income	**-0.002**	**0.001**	**-0.007**	**0.001**	**-0.005**	**0.006**
		(2.41)*	(0.56)	(10.08)**	(0.23)	(4.23)**	(2.77)**
	Sex (Male=1)	**-0.421**	**-0.007**	**-0.244**	**-0.008**	**-0.104**	**-0.383**
		(13.19)**	(0.21)	(11.76)**	(0.16)	(2.80)**	(5.85)**
	Single HH with job	**0.627**	**0.454**	**0.394**	**0.576**	**0.537**	**0.557**
		(6.71)**	(4.50)**	(5.90)**	(3.35)**	(4.40)**	(2.92)**
	Single HH without job	**1.098**	**0.994**	**0.399**	**1.115**	**0.705**	**0.97**
		(7.46)**	(6.34)**	(3.58)**	(4.47)**	(3.58)**	(2.89)**
	Couple HH with job	**-0.089**	**-0.114**	**0.073**	**0.001**	**0.049**	**-0.193**
		(1.35)	(1.78)	(1.75)	0.00	(0.64)	(1.72)
	Couple HH without job	**0.432**	**0.496**	**0.286**	**0.525**	**0.24**	**0.25**
		(5.93)**	(7.84)**	(6.65)**	(5.17)**	(3.17)**	(1.67)
	HH, children without job	**0.511**	**0.212**	**0.045**	**0.206**	**-0.019**	**0.775**
		(7.36)**	(3.15)**	(1.05)	(2.10)*	-0.27	(5.99)**
	Retired HH	**0.236**	**0.183**	**0.316**	**0.212**	**0.259**	**-0.126**
		(5.01)**	(4.03)**	(10.94)**	(2.83)**	(4.95)**	(1.42)
	Younger than 16/18	**2.219**	**1.536**	**1.134**	**1.383**	**0.991**	**1.978**
		(45.71)**	(33.72)**	(34.58)**	(18.69)**	(17.47)**	(18.67)**
	Observations	145490			37144		19608

Base outcome= car
Absolute value of z statistics in parentheses
* significant at 5%; ** significant at 1%

Appendix Table 10.5 Mode Choice by Trip Distance in the U.S.

		USA / Mode of Transport All Trips as in Chapter 10			USA / Mode of Transport Trips < 1.6km		USA / Mode of Transport Trips >16km
		Transit	**Bike**	**Walk**	**Bike**	**Walk**	**Transit**
	Constant	**-3.763**	**-5.022**	**-1.968**	**-3.567**	**-0.859**	**-3.802**
		(32.99)**	(26.01)**	(32.46)**	(12.95)**	(11.04)**	(18.34)**
Policy	Transit access <400m	**0.044**	**0.082**	**0.194**	**-0.254**	**0.133**	**0.175**
		(0.83)	(0.82)	(5.87)**	(1.83)	(3.01)**	(1.65)
	Transit access 400-1000m	**-0.193**	**-0.106**	**0.003**	**-0.13**	**0.001**	**-0.4**
		(2.72)**	(0.85)	(0.07)	(0.74)	(0.01)	(2.69)
Spatial development patterns	Population density	**0.149**	**0.085**	**0.156**	**0.027**	**0.115**	**0.132**
		(8.88)**	(2.52)*	(16.69)**	(0.58)	(8.72)**	(4.10)**
	Mix of use	**-0.133**	**0.137**	**0.282**	**-0.41**	**-0.039**	**0.127**
		(1.45)	(0.85)	(5.24)**	(1.73)	(0.54)	(0.69)
Trip Purpose	Work trip	**0.397**	**-1.197**	**-1.255**	**-0.544**	**-0.633**	**0.633**
		(6.00)**	(7.68)**	(30.04)**	(2.57)*	(12.17)**	(5.36)**
	Shopping trip	**-1.915**	**-1.514**	**-1.225**	**-1.444**	**-1.375**	**-2.257**
		(19.03)**	(10.75)**	(33.83)**	(8.70)**	(30.95)**	(8.90)**
Socioeconomic and demographic variables	Car access/availability	**-0.783**	**-0.304**	**-0.578**	**-0.432**	**-0.504**	**-0.700**
		(11.16)**	(3.13)**	(14.02)**	(3.23)**	(10.47)**	(5.46)**
	Household income	**-0.005**	**-0.002**	**-0.001**	**-0.002**	**0.001**	**-0.003**
		(7.49)**	(2.00)*	(1.28)	(1.14)	(1.60)	(1.82)
	Sex (Male=1)	**0.041**	**0.723**	**-0.014**	**0.712**	**0.08**	**-0.017**
		(1.00)	(9.06)**	(0.53)	(6.71)**	(2.26)*	(0.19)
	Single HH with job	**0.569**	**0.386**	**0.459**	**0.118**	**0.43**	**-0.023**
		(4.02)**	(1.52)	(6.93)**	(0.33)	(5.09)**	(0.09)
	Single HH without job	**1.192**	**0.797**	**0.828**	**-1.193**	**0.746**	**0.456**
		(4.30)**	(1.76)	(6.05)**	(1.16)	(3.90)**	(0.80)
	Couple HH with job	**0.274**	**0.252**	**0.207**	**-0.121**	**0.286**	**-0.143**
		(2.66)**	(1.54)	(4.83)**	(0.46)	(5.05)**	(0.95)
	Couple HH without job	**1.193**	**0.104**	**0.305**	**0.048**	**0.351**	**0.003**
		(6.60)**	(0.22)	(3.60)**	(0.07)	(3.06)**	(0.01)
	HH, children without job	**0.679**	**-0.164**	**0.154**	**-0.325**	**0.077**	**0.225**
		(4.32)**	(0.58)	(2.55)*	(0.77)	(0.93)	(0.70)
	Retired HH	**-0.156**	**-0.114**	**0.117**	**-0.298**	**0.115**	**-0.833**
		(1.14)	(0.76)	(2.77)**	(1.39)	(2.05)*	(3.32)**
	Younger than 16/18	**2.884**	**1.69**	**0.575**	**1.743**	**0.531**	**2.63**
		(38.49)**	(15.42)**	(15.46)**	(11.04)**	(10.69)**	(20.08)**
	Observations	198484			46192		42771
Base outcome= car							
Absolute value of z statistics in parentheses							
* significant at 5%; ** significant at 1%							

Appendix Table 10.6 MNLM by Country

		Germany / Mode of			USA / Mode of Transport		
		Transit	**Bike**	**Walk**	**Transit**	**Bike**	**Walk**
	Constant	**-2.441**	**-1.116**	**-0.456**	**-3.763**	**-5.022**	**-1.968**
		(24.90)**	(12.64)**	(7.57)**	(32.99)**	(26.01)**	(32.46)**
Policy	Transit access <400m	**0.558**	**0.043**	**0.501**	**0.044**	**0.082**	**0.194**
		(9.08)**	(0.86)	(13.59)**	(0.83)	(0.82)	(5.87)**
	Transit access 400-1000m	**0.31**	**0.008**	**0.301**	**-0.193**	**-0.106**	**0.003**
		(4.84)**	(0.15)	(7.91)**	(2.72)**	(0.85)	(0.07)
Spatial developme nt pattern	Population density	**0.392**	**-0.013**	**0.116**	**0.149**	**0.085**	**0.156**
		(30.23)**	(0.93)	(12.79)**	(8.88)**	(2.52)*	(16.69)**
	Mix of use	**0.159**	**0.483**	**0.311**	**-0.133**	**0.137**	**0.282**
		(1.38)	(4.66)**	(4.20)**	(1.45)	(0.85)	(5.24)**
Trip Purpose	Work trip	**0.613**	**0.02**	**-1.13**	**0.397**	**-1.197**	**-1.255**
		(16.19)**	(0.53)	(33.06)**	(6.00)**	(7.68)**	(30.04)**
	Shopping trip	**-0.654**	**-0.188**	**-0.266**	**-1.915**	**-1.514**	**-1.225**
		(16.31)**	(5.92)**	(12.42)**	(19.03)**	(10.75)**	(33.83)**
Socioeconomic and demographic variables	Car access/availability	**-2.236**	**-1.696**	**-1.277**	**-0.783**	**-0.304**	**-0.578**
		(34.06)**	(29.26)**	(29.71)**	(11.16)**	(3.13)**	(14.02)**
	Household income	**-0.002**	**0.001**	**-0.007**	**-0.005**	**-0.002**	**-0.001**
		(2.41)*	(0.56)	(10.08)**	(7.49)**	(2.00)*	(1.28)
	Sex (Male=1)	**-0.421**	**-0.007**	**-0.244**	**0.041**	**0.723**	**-0.014**
		(13.19)**	(0.21)	(11.76)**	(1.00)	(9.06)**	(0.53)
	Single HH with job	**0.627**	**0.454**	**0.394**	**0.569**	**0.386**	**0.459**
		(6.71)**	(4.50)**	(5.90)**	(4.02)**	(1.52)	(6.93)**
	Single HH without job	**1.098**	**0.994**	**0.399**	**1.192**	**0.797**	**0.828**
		(7.46)**	(6.34)**	(3.58)**	(4.30)**	(1.76)	(6.05)**
	Couple HH with job	**-0.089**	**-0.114**	**0.073**	**0.274**	**0.252**	**0.207**
		(1.35)	(1.78)	(1.75)	(2.66)**	(1.54)	(4.83)**
	Couple HH without job	**0.432**	**0.496**	**0.286**	**1.193**	**0.104**	**0.305**
		(5.93)**	(7.84)**	(6.65)**	(6.60)**	(0.22)	(3.60)**
	HH, children without job	**0.511**	**0.212**	**0.045**	**0.679**	**-0.164**	**0.154**
		(7.36)**	(3.15)**	(1.05)	(4.32)**	(0.58)	(2.55)*
	Retired HH	**0.236**	**0.183**	**0.316**	**-0.156**	**-0.114**	**0.117**
		(5.01)**	(4.03)**	(10.94)**	(1.14)	(0.76)	(2.77)**
	Younger than 16/18	**2.219**	**1.536**	**1.134**	**2.884**	**1.69**	**0.575**
		(45.71)**	(33.72)**	(34.58)**	(38.49)**	(15.42)**	(15.46)**
Model Fit	Observations	145490			198484		
	McFadden R-Square	9.30%			11.10%		
	Cox-Snell R-Square	18.50%			9.40%		
	Nagelkerke R Square	20.80%			15.90%		
	Log Likelihood Intercept	-159420.09			-88821.9		
	Log Likelihood Full	-144583.3			-78997.5		
	Probability> Chi Square	0.000			0.000		

Base outcome= car

Absolute value of z statistics in parentheses

* significant at 5%; ** significant at 1%

Appendix Table 10.7 Marginal Effects After MNLM

	Germany				USA			
	Car	Transit	Walk	Bike	Car	Transit	Walk	Bike
Transit access <400m	-0.092	0.023	-0.011	0.080	-0.013	0.000	0.000	0.012
Transit access 400-1000m	-0.055	0.013	-0.009	0.050	0.002	-0.002	-0.001	0.000
Population density	-0.029	0.020	-0.006	0.016	-0.011	0.001	0.000	0.009
Mix of use	-0.080	0.002	0.037	0.042	-0.016	-0.002	0.001	0.017
Work trip	0.365	-0.096	-0.114	-0.156	0.044	-0.008	-0.001	-0.034
Shopping trip	0.001	0.000	0.000	-0.001	0.000	0.000	0.000	0.000
Car access/availability	0.049	-0.020	0.008	-0.037	-0.003	0.000	0.004	-0.001
Household income	-0.110	0.031	0.030	0.049	-0.042	0.007	0.002	0.032
Sex (Male=1)	-0.175	0.066	0.095	0.014	-0.094	0.021	0.005	0.068
Single HH with job	-0.001	-0.005	-0.011	0.017	-0.017	0.003	0.001	0.013
Single HH without job	-0.090	0.018	0.041	0.031	-0.042	0.023	0.000	0.019
Couple HH with job	-0.041	0.031	0.016	-0.006	-0.018	0.010	-0.001	0.009
Couple HH without job	-0.065	0.008	0.008	0.050	-0.005	-0.002	-0.001	0.007
HH, children without job	-0.348	0.146	0.104	0.098	-0.131	0.087	0.013	0.031
Retired HH	0.095	0.057	0.019	-0.171	0.057	0.006	-0.004	-0.058
Younger than 16/18	0.070	-0.028	-0.008	-0.034	0.074	-0.013	-0.005	-0.055

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2004 – 2007 — **Rutgers University, Bloustein School of Planning and Public Policy,** Teaching Assistant

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PEER REVIEWED PUBLICATIONS

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