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**ifmo**

Institute for Mobility Research



# THE FUTURE OF DRIVING IN DEVELOPING COUNTRIES

Liisa Ecola, Charlene Rohr, Johanna Zmud  
Tobias Kuhnimhof, Peter Phleps



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BUCKLE UP





## **The Future of Driving in Developing Countries**

Liisa Ecola, Charlene Rohr, Johanna Zmud,  
Tobias Kuhnimhof, Peter Phleps

The research described in this report was sponsored by the Institute for Mobility Research (ifmo) and conducted in the Transportation, Space, and Technology Program within RAND Justice, Infrastructure, and Environment.

As a part of the agreement under which the research described in this document was funded, RAND grants the Institute for Mobility Research a nonexclusive, royalty-free license to duplicate and distribute this publication in any medium, either commercially or non-commercially.

Library of Congress Cataloging-in-Publication Data is available for this publication.  
ISBN: 978-0-8330-8604-4

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# Foreword

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All over the world, mobility of people is associated with increasing economic output and higher standards of living. As incomes grow, people travel more for business and leisure activities than they have in the past. This relationship holds true for industrialized, as well as for emerging, economies. Still, large intercountry differences in the amount that people travel are not explained by income growth alone. For example, at the same average level of income, people in Japan travel about one-third the number of kilometers (per capita) that people in the United States do. Such factors as spatial dispersion, car culture, fuel prices, and regulation contribute to explaining these differences. By exploring the historical development of mobility in the past 100 years and the conditions that currently influence mobility, this report sheds light on these relationships.

Hypothesizing that these relationships may hold true for emerging economies in the future, our observations about historical and current influences in developed countries can serve as valuable input in predicting mobility in emerging economies. Thus, after explaining the evolution of mobility in industrialized countries, the present report examines mobility conditions in emerging economies and projects them into the future. Applying the basic relationships found for industrialized countries to emerging economies, the report predicts future mobility levels in Brazil, Russia, India, and China (the BRIC countries).

Thus, the present report makes two major contributions:

1. Most studies explaining mobility levels apply gross domestic product as the main explanatory factor. The present report goes beyond this, incorporating nine factors that influence mobility evolution. This is a major contribution in understanding the differences in mobility levels between countries.
2. Applying these nine factors for predicting mobility levels in the BRIC countries provides a solid ground for taking a future-oriented perspective on the mobility of people in emerging economies.

Against this background, the report is highly relevant for planners, scientists, providers of mobility services and products, and all other stakeholders dealing with the future of mobility in emerging economies.

Dr. Irene Feige  
Head of the institute  
ifmo

# Preface

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It is well-accepted that mobility—the ability to travel from one location to another—contributes to well-being and quality of life. Although the need for mobility is universal, the amount of and demand for mobility varies greatly from country to country. The purpose of the research reported here was to look at whether mobility in developing countries will follow similar paths as it did in countries that developed in the 20th century.

Although all modes of travel are important, the research reported here focused on automobility, which has become an important part of providing mobility in developed countries. In most developed countries, travel by automobile has become the dominant mode by far, even as the amount of travel that takes place on transit or by nonmotorized modes varies a fair amount. However, major differences in vehicle ownership and use remain, even among developed countries of similar income levels. This research sought to understand the basis for these remaining differences.

From there, we extrapolated how countries just beginning on the path to motorization may differ from each other and from countries that are already developed. To accomplish this, we developed a methodology that combines quantitative and qualitative information to forecast future trends in automobility for four large developing countries.

This study was sponsored by the Institute for Mobility Research, known by its German abbreviation ifmo. The results should be of interest to policymakers and decisionmakers concerned with the long-term future of transportation in developing economies, as well as those interested in what broad influences affect mobility beyond economic development. RAND Corporation researchers are also working on other research into the long-term future of transportation. For the Transportation Research Board, RAND researchers are conducting long-term strategic studies, looking at options for adopting alternatively fueled vehicles, incorporating new technologies into the transportation system (Popper et al., 2013), and evaluating the impact of sociodemographic changes. RAND researchers have also worked with ifmo on a scenario study for the United States (Zmud et al., 2013).

## The RAND Transportation, Space, and Technology Program

The research reported here was conducted in the RAND Transportation, Space, and Technology Program, which addresses topics relating to transportation systems, space exploration, information and telecommunication technologies, nano- and biotechnologies, and other aspects of science and technology policy. Program research is supported by government agencies, foundations, and the private sector.

This program is part of RAND Justice, Infrastructure, and Environment, a division of the RAND Corporation dedicated to improving policy and decisionmaking in a wide range of policy domains, including civil and criminal justice, infrastructure protection and homeland security, transportation and energy policy, and environmental and natural resource policy.

Questions or comments about this report should be sent to the project leader, Johanna Zmud (Johanna\_Zmud@rand.org). For more information about the Transportation, Space, and Technology Program, see <http://www.rand.org/transportation> or contact the director at [tst@rand.org](mailto:tst@rand.org).

## The Institute for Mobility Research

The Institute for Mobility Research is a research facility of the BMW Group. It deals with future developments and challenges relating to mobility across all modes of transport, with automobility being only one aspect among many. Taking on an international perspective, ifmo's activities focus on social science and sociopolitical, economic, and ecological issues, and also extend to cultural questions related to the key challenges facing the future of mobility. The work of the institute is supported by an interdisciplinary board of renowned scientists and scholars and by representatives of the BMW Group, Deutsche Bahn, Lufthansa, MAN, Siemens, and the World Bank.

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# Summary

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## Mobility and Automobility

The need for mobility—that is, the need to travel from one location to another—is universal. People travel to earn a living, conduct personal business, attend school, visit relatives, and worship. Yet, despite these common demands for travel, mobility varies greatly from country to country and over time. The amount that people travel and the modes they use vary with a host of factors. A key goal of the research reported here was to better understand the factors that underlie differences in how mobility has evolved.

One main factor is the availability of new technologies. New technologies have reduced travel times and facilitated very different spatial patterns since the age when walking and riding horses or horse-drawn vehicles were the only ways to travel over land. These new technologies spread quickly when societies can afford to build them and individuals can afford to use them.

In the past century, the most important new technology for moving people has been the car. Although the technological breakthroughs that made internal combustion and electric engines possible took place in the late 1800s, only in the 1910s did cars become sufficiently affordable and reliable to enter the market as a mass consumer good. Since then, cars have entered nearly every country and played a variety of roles. Cars enable suburban commuting and the geographic separation of commercial and residential areas, allow long-distance trips with no fixed schedule, and serve as status symbols. They also produce disbenefits: congested roads, injuries and deaths in crashes, and air pollution.

Another main factor is the level of economic development, whose effect shows up in many ways. At the national level, the total amount of travel tends to increase as the economy grows. Broadly speaking, people in countries with higher levels of economic development tend to travel more than those in countries with lower levels do. Within countries, people with higher incomes tend to travel more than those with lower incomes.

However, the impact of both new technologies and economic development varies from country to country, and that observation underpins the research reported here. We are interested in the “evolutionary paths” of mobility in different countries—that is, why do countries at similar levels of economic development vary so much in the amount and mode of travel? And more importantly, what can this understanding tell us about the potential future paths of mobility in countries with rapidly growing economies?

The need for sufficiently comparable data across countries required a focus on automobility, despite our preference to examine all forms of mobility. By automobility, we mean mobility that is served by privately owned personal vehicles (generally, we use the term *personal vehicle* to mean any car or light truck that is driven for personal use). Although all data have some inconsistencies across countries, data on vehicle ownership and kilometers driven tend to be collected more consistently than data about transit use or nonmotorized modes. In addition, automobility is a key source of mobility in all developed countries, although its use does vary, and the use of personal vehicles in developing countries may have a major impact on the world oil market, levels of carbon emissions, and automotive industries.



Our hypothesis is that, although income data tell us something important about how quickly the amount of driving increases in a country, income has a far lesser effect on the saturation level. That is, we expect vehicle-kilometers traveled (VKT) to increase with a country's gross domestic product (GDP), but we do not expect it to predict the saturation level. We define saturation level as the level at which VKT per person stabilizes. We are then interested in what other factors influence the saturation level and the extent to which the factors that have been important in developed countries will influence the saturation levels in developing countries. Put a pithier way, as the Chinese economy develops, will people in China drive more like people in the United States or more like people in Japan?

## Understanding the Influences on Automobility

To address this question, we chose a mixture of quantitative and qualitative methods. As noted above, we decided to focus on automobility for reasons of data availability and comparability. We selected VKT as the main indicator of automobility because, despite some problems, VKT data were available for most countries. (Although we considered vehicle ownership as another indicator, vehicle ownership varies less between countries, and, for the sake of simplicity, we chose to focus on just one indicator.)

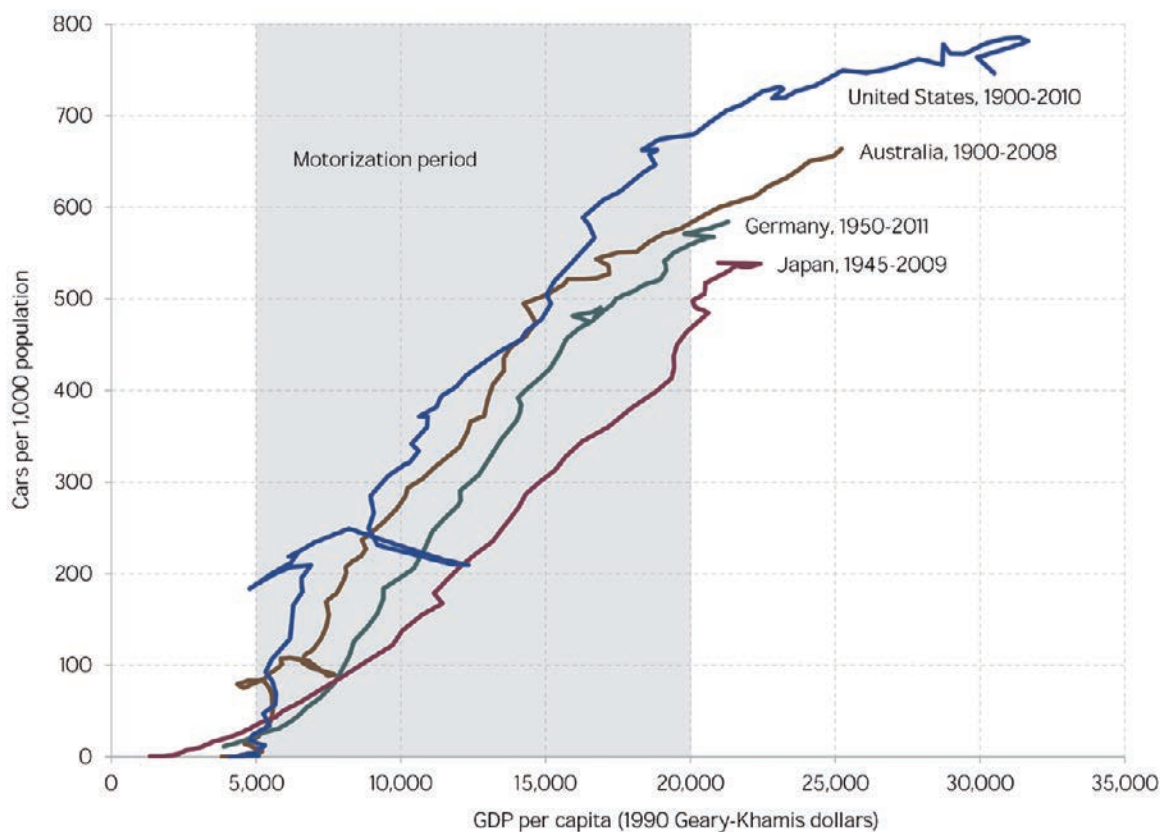
We then selected four developed countries as case studies of the different ways in which mobility evolves. We compared several dozen countries in the Organisation for Economic Co-Operation and Development (OECD) to find those with the most dissimilar levels of VKT at similar levels of development. Of the countries we considered, Japan has the lowest VKT per capita and the United States has the highest, so those formed the outer limits of VKT among developed countries. We also selected Germany as a typical European country, as well as Australia, which is similar to the United States in many respects but has markedly lower VKT per capita. We also decided to use Brazil, Russia, India, and China—the BRIC countries—as the developing countries. Roughly one-half of the world's population lives in one of these eight countries.

For each OECD case study, we developed a narrative about the long-term history of mobility. The purpose of this narrative was to understand the influences of a variety of factors—ranging from policies to industrial development to turning points, such as war—on the way in which mobility developed. In addition, we also conducted a literature review of empirical research into other influences on mobility. From these sources, we developed lists of potential factors other than economic development that seemed to affect mobility. We ultimately identified nine factors in two groups: transportation policy factors and exogenous factor.

Using data on per capita GDP and VKT as far back as available, we developed anticipated saturation levels of VKT per capita for each country. These levels were based on a model fitted to the data for each country. Although we attempted to develop a general model to explain growth in VKT as a function of GDP, the results did not fit nearly

as well as the country-specific models, which supports our hypothesis that factors other than GDP play a role in the saturation level for each country. The saturation levels ranged from 16,300 VKT per capita in the United States to 6,400 VKT per capita in Japan.

For each OECD country, we identified a “motorization” period, defined by two decades: the decade in which GDP per capita surpassed \$5,000 (all GDP figures for this exercise were based on international purchasing power parity calculations, to control for fluctuations in currency values) and the decade in which it exceeded \$20,000. The \$5,000 per capita seems to be the rough threshold at which personal vehicle ownership starts rising more quickly; at that level of GDP, personal vehicles tend to become affordable to a larger segment of the population. By \$20,000 GDP per capita, motorization slows because most households that wanted to own vehicles have already purchased them. See Figure S.1.



**Figure S.1. Motorization Rates and GDP Per Capita Growth for OECD Member Countries in This Study**

SOURCES: For GDP per capita, Bolt and van Zanden, 2013. For personal vehicle ownership, see Appendix A for individual country sources.

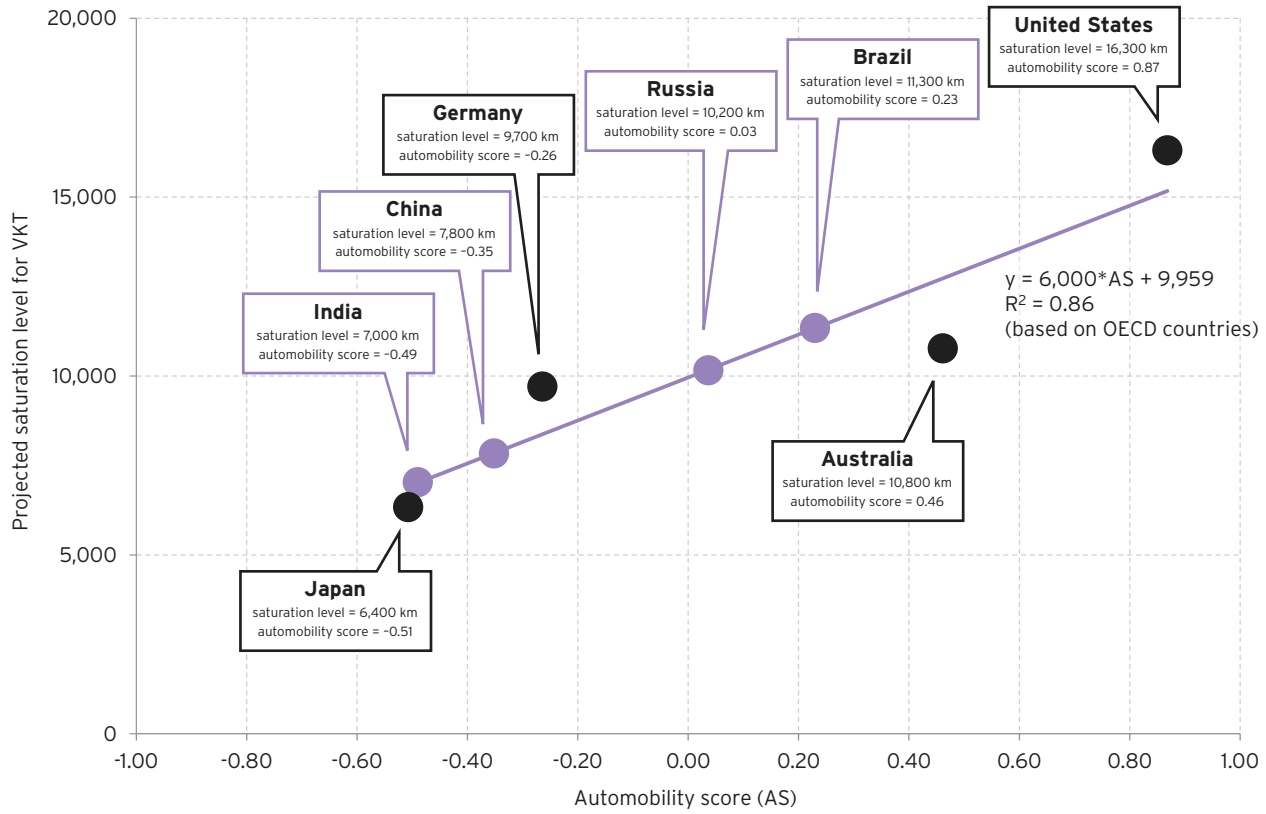
NOTE: Geary-Khamis dollars are dollars adjusted to account for purchasing power parity between countries. See Chapter Three for details.

We then used an expert elicitation exercise to quantify how the nine factors have changed for the OECD countries over time and how much they might change in the future for the BRIC countries. At a workshop, experts representing the eight countries rated the situation at the beginning and end of the motorization period for each of the nine factors, on a scale of -2 to 2. A score of 2 indicates a situation conducive to automobility, while a score of -2 indicates a situation that discouraged automobility. These judgments were produced for all eight countries, on a historical basis for the OECD and on a speculative basis for the BRIC countries, according to the decade in which incomes reached or were forecasted to reach \$20,000 per capita.

The experts also weighted the relative strength of each factor on a scale of 1 to 3. These factor scores and weights were combined into one overall automobility score for each country, which took into account the scores and weights at both the starts and ends of the motorization periods.

Our final step was to see what we could forecast about saturation levels in developing countries using these scores, given what we had learned earlier about saturation levels in the OECD countries. We regressed the automobility scores on the saturation levels estimated by the individual country models to see whether the automobility scores accurately forecasted the saturation levels.

Then we used the same regression model to forecast the saturation levels in the BRIC countries. If automobility scores are a reliable indicator of future travel, then the BRIC countries will tend to reach lower saturation levels than the countries that have developed economies today. For example, the model forecasted that both China and India would have saturation levels between 7,000 and 8,000 VKT per capita, higher than that of Japan (6,400 VKT per capita) but lower than that of Germany (9,700 VKT per capita). Russia's would be slightly higher than Germany's (10,200 VKT per capita), while Brazil is forecasted to reach a saturation level of 11,300 VKT, higher than that of Australia (10,800) but still far below that of the United States (16,300). See Figure S.2.



**Figure S.2. Automobility Scores and Forecasts of Long-Term Travel Saturation Levels**

SOURCE: Project workshop (see Chapter Six).

NOTE: Rounded to nearest 100.

## Implications and Observations

We draw three main policy implications from this work and provide some caveats and thoughts about future research:

- › First, income is not destiny. Most of the work done in the area of long-range forecasting of automobility has used income as the primary or only variable. Although there is a strong correlation between income growth and growth in vehicle travel (both per capita and total), income levels alone are not good predictors of travel demand. We thus forecasted a wide range of saturation levels in the four developing countries.
- › Second, this work seems to confirm our hypothesis that economic growth is quite helpful in understanding changes in demand for automobility over time within one country but far less helpful in understanding variation in demand between countries. To more fully understand the differences between countries, we needed to include other factors. Relying exclusively on income in international comparisons has less explanatory power than a method that incorporates additional factors.
- › Third, the experts identified spatial dispersion and car infrastructure as the most important of the nine factors. This suggests that policymakers can steer some elements of travel demand if desired. Although rising incomes tend to encourage driving, this can be countered by other policy measures; especially in developing countries, where infrastructure and spatial patterns are still being developed, there are opportunities to dampen the demand for driving. Although this suggestion is not intended to discount the importance of exogenous factors, such as oil prices, it does suggest that policy-makers have some scope for action in this area.

These findings have some substantial caveats, of course. We have made forecasts about the situation in BRIC countries several decades from now, so these may prove to be incorrect. Other factors that did not play much of a role, if any, in development in the four OECD countries may be pivotal in the BRIC countries. Information technologies or new environmental considerations may play a large role in the future evolution of mobility in developing countries, for example.

This research could be extended in a variety of useful ways:

- › We could attempt to estimate the speed at which the forecasted saturation levels are reached. That is, we could use estimated GDP growth to say something about how soon each BRIC country might reach the forecasted saturation levels. (Interestingly, the country-specific models do not show all four OECD countries as having reached saturation yet, although that might be a function of the models.)
- › We could conduct sensitivity analyses on the existing factors to see whether the regression model results can be more accurate. We could consider different factors and other countries.
- › We could look at vehicle ownership or other forms of mobility. The qualitative-quantitative methodology developed for this report could be useful in addressing these related questions because they are likely influenced by a combination of economic and other factors as well.

# Acknowledgments

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This work would not have been possible without the assistance of many people in and outside of RAND. Researchers at RAND Europe's Cambridge office assisted with developing case studies, assembling data, and developing econometric models of car ownership and vehicle-kilometers traveled, each of which required enormous attention to detail. In this regard, we thank Flavia Tsang, Gavin Cochrane, Hui Lu, James Fox, Andrew Daly, and Sunil Patil. Duncan Amos, a former research assistant at RAND in the United States, also assisted with assembling country-specific data.

Experts from the eight countries participated in a workshop whose results were integral to developing the forecasts detailed in Chapter Six. We are very grateful to the following country experts for their vital contributions: Jeffrey Kenworthy from Australia; Luiz Afonso dos Santos Senna, Antonio Nelson Rodrigues da Silva, and Emilio Merino Dominguez from Brazil; Lu Huapu and Yu Ding from China; Uwe A. Kunert from Germany; Toshiyuki Yamamoto from Japan; Ashish Verma, Senathipathi Velmurugan, and Subhamay Gangopadhyay from India; and Konstantin Trofimenko, Yelena Koncheva, and Egor Muleev from Russia.

We especially thank our two reviewers—Kelly J. Clifton, professor of civil and environmental engineering at Portland State University, and Thomas Light, an economist at RAND—for their very helpful comments on the draft, which have resulted in a better report. Steven W. Popper and Debra Knopman, both of RAND, made valuable comments as well. Finally, we thank Andria Tyner at RAND for her able administrative support.









Chapter One  
Introduction

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## Study Objectives

In developed countries, travel demand has generally increased along with economic development. The historically high growth in passenger mobility—specifically, demand for personal vehicle travel—has leveled off in recent years with some signs of saturation. However, current evidence suggests that this saturation occurs at very different levels in different countries; high-income countries show different levels of motorization (personal vehicles per capita) and vehicle travel demand (vehicle-kilometers traveled [VKT] per capita),<sup>1</sup> even at similar levels of gross domestic product (GDP) per capita. This indicates that, although economic development explains much of mobility development, other factors affect mobility as well.

This study began with three questions:

- › First, what factors besides economic development affect automobility? We see very different paths of mobility in countries with similar levels of income, so this question seeks to understand what other factors are in play.
- › Second, how can we assess the influence of these factors? We need to understand when and by what mechanisms they influence mobility.
- › Third, what will happen to automobility in developing countries if those same factors have similar influence? In other words, can we forecast whether, as incomes rise in China, people in China will drive as much as people in the United States or as little as people in Japan?<sup>2</sup>

These are wide-ranging questions, and, as a practical matter, we had to bound the study in two ways. First, ideally, we would have liked to have been able to look broadly at all forms of mobility—driving, transit, and nonmotorized modes. However, given the difficulty of finding comparable data across countries for all travel modes, realistically, we ended up focusing on driving. Although this approach is certainly not comprehensive, there are still important reasons to assess travel by personal vehicle. Despite the differences between developed countries, travel by personal vehicle is generally the most prevalent travel mode, capturing more kilometers traveled than transit or nonmotorized modes. In addition, the substantial differences in personal vehicle travel per capita in developed countries tell us much about the differences in mobility behavior in general.

Second, we would have liked to have been able to forecast two outcomes for mobility in developing countries: the speed at which countries increase their driving, as well as how much they eventually drive (the saturation level, as defined later). However, because of the limits of available data, we were able to address only the question of saturation level. In other words, to answer the above question about how much Chinese drivers will drive, we can estimate how much they eventually drive but not when that will happen.

To address these questions with regard to automobility, we developed a mixed methodology that combines three items: quantitative and qualitative information for four case studies of developed countries, expert opinion, and models of future travel demand. The following chapters outline this methodology and use the information gathered to develop forecasts of levels of saturation in travel demand in developing countries.

<sup>1</sup> Given the widespread use of VKT over vehicle-miles traveled (VMT), the more common indicator in the United States, this report uses VKT exclusively.

<sup>2</sup> Throughout this report, we use *forecast* to refer to our methods to estimate future values and the estimated values themselves. *Predict* and *project* imply more precision than we can claim.

## Report Organization

In addition to this introduction, this report contains seven chapters. Chapter Two explores the idea of evolutionary paths of mobility and whether and how this evolution in developed countries may prefigure a similar evolution in large developing countries. That chapter also defines our key analytical concepts. Chapter Three presents the methodology and data sources used. Chapter Four provides a brief introduction to the evolution of mobility in four developed countries. Chapter Five provides background on each factor that we believe affects the level of mobility. Chapter Six presents our analysis of these factors and describes how the results of our analysis can forecast future mobility in four developing countries. Chapter Seven provides our conclusions. We also include four appendixes: Appendix A on our data sources, Appendix B listing our travel demand experts, Appendix C providing our fact sheets, expert observations, and factor scores, and Appendix D explaining how we estimated the parameters for our model.

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# Chapter Two

## Evolutionary Paths of Mobility

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This chapter explores the concepts and definitions of mobility, automobility, evolutionary paths, saturation levels, and motorization. We also discuss our assumptions about the influences on automobility.

## What Is an “Evolutionary Path of Mobility”?

We define mobility as the ability to travel from one location to another. Although greater mobility is not always associated with increasing standards of living or only positive outcomes, we do assume that mobility is generally desirable. People travel to meet important needs, such as employment, social interactions, religious services, and medical care.<sup>1</sup>

People meet their mobility needs through the modes available to them; in turn, these modes often shape the physical form of settlements. Cities or their component neighborhoods that were settled before motorized transportation was available developed around the need to walk or travel by horse, both of which led to more compact settlements. When rail became prevalent, it enabled both faster travel between cities and expansion of the cities themselves. The introduction of affordable personal vehicles into the consumer marketplace more than a century ago allowed greater spatial dispersal, along with more personal freedom to travel longer distances on one’s own schedule.

The concept of an evolutionary path implies that the way in which people meet their mobility needs changes over time. Regardless of income levels, most countries have experienced transformations in mobility. As a result, a variety of modes—motorized and nonmotorized, public and private—generally exist side by side, and people use the modes that best match their mobility needs and their financial means.

We define an evolutionary path of mobility as a series of changes over long time periods in the ways in which people travel or in the amount of travel using different modes. For example, one country might move quickly into personal vehicle ownership and thus higher rates of driving when rising income levels make vehicles affordable to a large number of households. Another country might experience more gradual growth in travel by personal vehicle over many decades. A third country might be slower to adopt personal vehicle ownership because existing travel modes already meet mobility needs or because policies limit vehicle purchases or vehicular travel. Over time, these changes in mobility influence settlement patterns and urbanization, household wealth (if vehicles are expensive yet important, some people may purchase vehicles but allot less money to other needs), pollution and other emissions that affect the local and global environment, and even mortality (vehicle crashes are a leading cause of death in many countries). In this research, we were particularly concerned with the evolution of mobility in the past century, since automobiles were introduced.

We see evidence that mobility evolves differently in different countries by comparing indicators that measure different aspects of mobility, such as vehicle ownership or use of public transit. Also, mobility continues to evolve; even for countries in which we might expect to see some type of saturation, changes continue to occur. The evolution of mobility is not a wholly predictable march to some preordained saturation point; rather, it occurs in the context of many exogenous changes, such as mobility policies, infrastructure development, attitudes, costs, and technology.

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<sup>1</sup> There is an ongoing discussion in the literature about whether the goal of a transportation system should be accessibility as opposed to mobility. A focus on accessibility means that people can meet these needs without extensive travel; that is, residential neighborhoods would also contain retail, offices, and other services so that many needs could be met with shorter travel distances, particularly on foot or bicycle. Although this is an important argument, it is not the focus of this study.

## What Influences Mobility?

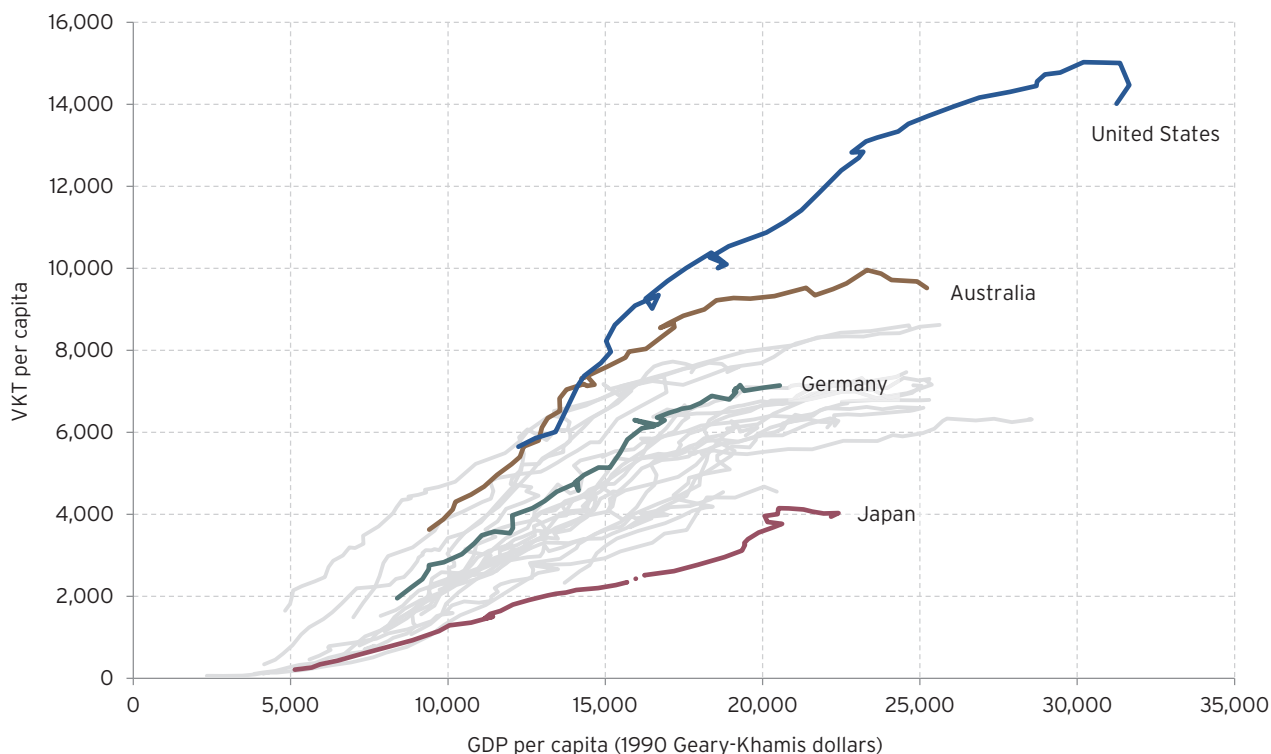
One goal of this research was to better understand the factors that underlie differences in how mobility has evolved. Chapter Three explains in greater detail why we selected the indicators we did; our main focus in this report is automobility, or mobility provided by personal vehicles.<sup>2</sup> We use the term *automobility* in this broad sense; we use *motorization* to refer specifically to personal vehicle ownership.

Travel in personal vehicles makes up the largest share of mobility in most developed countries, and personal vehicle travel also produces substantial negative externalities (e.g., pollution and congestion). In addition, the availability of data to measure use of other modes consistently across a range of countries was limited, for reasons discussed in Chapter Three. Therefore, we focused our research on explaining the use of personal vehicles.

A key contributor to high levels of automobility is economic development (Dargay and Gately, 1999). It is difficult to reach high levels of mobility without personal vehicle ownership, and, in both cross-national comparisons and within-country comparisons over time, automobility goes hand in hand with increasing economic development. Although there is no conclusive research on the causal relationship between economic development and VKT (see Ecola and Wachs, 2012, for a discussion of the U.S. literature on this topic), certainly the data suggest that there is correlation. Figure 2.1 shows the relationship between per capita VKT and GDP for 25 Organisation for Economic Co-Operation and Development (OECD) countries. (The four countries highlighted are the case-study countries for this study; more on their selection in Chapter Three.)

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<sup>2</sup> Throughout this report, we use the term *personal vehicle* to denote privately owned cars and light-duty trucks that are driven for personal use. This term does not generally include such vehicles as motorcycles or bicycles. Passenger vehicle can also mean larger vehicles that carry paying passengers (such as buses or vans used for vanpools), so that is considered a different mode.



**Figure 2.1. Vehicle-Kilometers Traveled and GDP Per Capita for 22 Countries, 1963-2008**

SOURCES: VKT and population data are from national sources for the four case-study countries (see Appendix A for details). For the other 18 countries, those data are from Australia Bureau of Infrastructure, Transport and Regional Economics (BITRE), 2012b. GDP data are from Bolt and van Zanden, 2013.

NOTE: The split in Japan data denotes the inclusion of “trucks for private use” in VKT from 1987.

Yet, even in developed countries with similar levels of GDP per capita, we see substantial differences in automobility. As Figure 2.1 shows, all the lines slope upward to the right, indicating that, as GDP grows, VKT also grows. However, although similar, they are not identical. For example, at roughly \$20,000 GDP per capita,<sup>3</sup> Japanese drivers drive less than half as many kilometers as American drivers. This clearly indicates that, although GDP is an important factor, factors other than GDP contribute substantially to differences in automobility as well. This project seeks to identify and understand the influence of those factors.

<sup>3</sup> See Chapter Three for a discussion of GDP per capita data.



## What Is a Saturation Level?

Figure 2.1 suggests two important concepts in thinking about evolution of automobility: the speed of growth and the saturation level. The speed of growth is defined as the rate of change in the level of annual VKT. This is indicated by the slope of a line; the steeper the slope, the faster the growth.

The saturation level is defined as a number of per capita VKT at which we do not expect any additional increases in driving, even if incomes rise. As Figure 2.1 shows, the line for each country follows a shape typically described as an S-curve. In our case, it means that automobility increases slowly at the lowest income levels, then increases more rapidly as incomes rise, and finally slows down and flattens out rather than continuing to increase. The saturation level is defined as this upper limit at which the curve flattens out. This is not an unusual pattern; adoption rates for new technologies often follow a similar S-curve.

Why does saturation matter? We believe that it can lead to several important changes in transportation policy. First, it means that the focus of policymaking around transportation infrastructure may shift from expansion to maintenance, especially as many countries are seeing population growth level off as well. A country with sufficient road infrastructure and a relatively stable population can shift its focus to upkeep and renovation rather than new capacity, or perhaps shift from expansion of passenger travel to freight. Second, given that saturation occurs in the context of high average incomes, it implies that most people's mobility demands are met. This implication points to the same conclusion—the transportation system can shift from expansion to maintenance—but may more broadly suggest that other public policy concerns can take precedence over transportation. Finally, saturation in driving does not necessarily mean that demand is saturated in all modes; it may imply that people are shifting some travel to transit, ride-sharing, or nonmotorized modes, in which resources might be shifted to infrastructure supporting those modes.

Our work is based on two important assumptions about saturation. The first assumption is that automobility naturally reaches some saturation point; that is, per capita VKT will not keep rising indefinitely, even if economic growth continues. This issue has been debated in the transportation literature; until quite recently, most countries have seen sustained growth in VKT over long periods of time, but several recent papers have argued that this long-term growth period is ending (see, for example, Millard-Ball and Schipper, 2011, and Goodwin, 2012).

The second assumption is that changes in GDP (or alternating periods of recession and growth) primarily affect the speed of automobility development, while other, non-economic factors have a greater impact on its saturation level. For example, Japan has experienced rapid economic development since the 1960s but has low automobility. In our view, the influence of rapid GDP growth on saturation levels has been mitigated by other factors, such as land use. Therefore, GDP growth has only a contributing, not a direct, influence on long-term saturation levels for automobility. (Other factors may also affect the speed of automobility growth; we do not claim that GDP growth is the only contributing factor.) Our focus in this project was on investigating what additional factors shape these saturation levels.

## What Is a Motorization Period?

Our hypothesis is that the factors that influence automobility, defined as VKT per capita, have their greatest influence when incomes have risen to a point at which personal vehicles are affordable to a large portion of the population. Looking at trends from developed countries, we defined the relevant study period as beginning in the decade when GDP per capita reached \$5,000 and ending in the decade when it reached \$20,000. We refer to this as a country's motorization period. By this definition, the motorization period lasts as long as it takes for a country's per capita income to grow from \$5,000 to \$20,000; it may be just a few decades, or as long as 70 years. Although some people own vehicles when per capita income is less than \$5,000 and other people continue to buy them after it reaches \$20,000, we can think of this period as the steepest part of the S-curve. Before it starts, vehicle ownership is generally restricted to the wealthiest citizens; after it ends, vehicle ownership is fairly common. So the motorization period roughly defines the length of time during which personal vehicles shift from being a luxury good to being a common one. Other work in this field—for example, Dargay, Gately, and Sommer (2007)—supports this definition. The selection of motorization periods is discussed in more detail in Chapter Three.

We distinguish between the motorization period and the point at which saturation is anticipated. The methodology we developed for this project required a basis on which to compare developed countries with developing countries. This was defined as the motorization period. However, both vehicle ownership and VKT may continue to increase after incomes reach \$20,000 per capita. Saturation in automobility is a long-term proposition; we do not attempt to estimate the level of income at which saturation occurs. Just as the saturation level varies between countries, so can the income level at which saturation takes place.

Similarly, we do not attempt to estimate the speed at which automobility develops. As Figure 2.1 shows, the speed, as represented by the slope of the line for each country, varies quite substantially. Our modeling work found that each country's speed differed, requiring different estimates to fit the model to the data. Conducting such work for Brazil, Russia, India, and China—the BRIC countries—would require developing detailed estimates of future GDP per capita growth and experimenting with various curves to determine the most reasonable assumptions about the relationship between economic and VKT growth. Such estimates and experiments were outside the scope of the current project.

## What Can Past Evolution Tell Us About Developing Countries?

In the past century, personal vehicles went from luxury to commonplace in developed countries. This coincided with certain trends: increasing personal incomes, greater industrial production, and the increase of the number of women in the workforce.

This research sought to understand how these insights regarding GDP growth and other contributing factors can help forecast how automobility might evolve in developing countries. In terms of economic development, developing countries are thus far following the same general rule as developed ones have: Automobility increases with income. Therefore, our assumption for this project was that other factors will also shape their long-run saturation levels in similar ways, although the relevance of specific factors may differ between countries.

Of course, this may prove not to be the case. Developing countries today are obviously developing under very different conditions from those that prevailed in the 20th century. Americans began manufacturing and buying cars in large numbers in an era when gasoline prices were not only relatively low but also stable; world oil prices (which drive gasoline prices) are now expensive and volatile. In addition, new influences may also play a role in mobility. Climate change and greenhouse gas (GHG) emissions, now important global concerns, were not even on the horizon as critical issues in the 1950s, when many other countries went through their period of highest growth in vehicle demand. Technologies, such as the Internet and smartphones, whose use is rising throughout the world, may bring about changes in mobility patterns that cannot yet be predicted. Yet we believe that even these new influences will be tempered by factors that shaped automobility in now-developed countries.

Can we use the information about developed countries to forecast whether China, for instance, might follow the U.S. path as opposed to the Japanese path? In the next chapters, we explore the factors other than economic growth that have shaped automobility and develop a methodology for determining what factors do so.



# Chapter Three

## Study Methodology

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This project consisted of four broad and occasionally overlapping tasks:

- › First, we selected a mobility indicator: VKT per capita. This decision was based on the availability of data sources. We also decided to use GDP per capita as the indicator of economic development.
- › Second, we identified eight countries to study. Four are developed countries that represent different evolutionary paths of mobility: Australia, Germany, Japan, and the United States. The other four are large developing countries, the BRIC countries.
- › Third, we selected factors that seemed to affect the evolutionary paths of the developed countries beyond the influence of economic development; selection of factors was based on a literature review, as well as case studies of OECD countries.
- › Fourth, we estimated how changes in these factors might affect mobility trends in the four developing countries, based on how they played out in the four case-study countries.

A schematic of these tasks is shown in Figure 3.1.



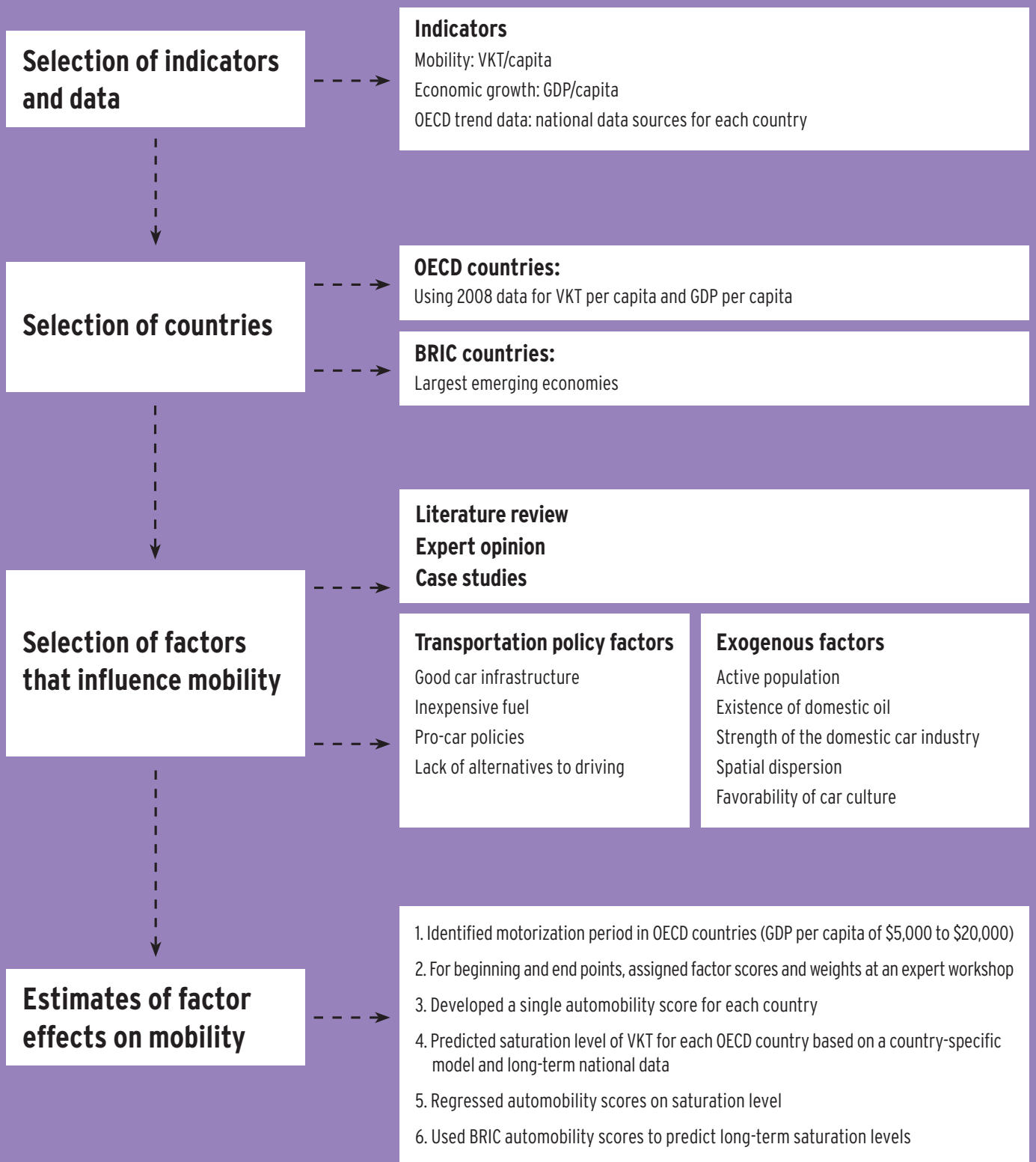


Figure 3.1. Diagram of Study Methodology

## Selecting Indicators and Data

To make comparisons across countries and long periods of time, we needed to identify specific indicators and sources of data. Because we could locate neither perfect indicators nor perfect data sources, the selection of indicators and data sources was carried out to some extent simultaneously by reviewing what was available and making decisions based on the needs of the project.

### Vehicle-Kilometers Traveled as a Mobility Indicator

Although we use a straightforward definition of mobility—the ability to travel from one location to another—mobility can be measured in many ways, so it is necessary to identify specific indicators. An indicator is defined as a unit of data that measures a condition that is not directly measurable. For example, the number of deaths in vehicle crashes is an indicator of traffic safety. Developing useful indicators is often constrained by the availability of good data with which to develop comparisons. No indicator is perfect or captures every important aspect.

Mobility is generally measured in two ways: distances traveled and number of trips taken. Although there are good reasons to use each depending on the issue to be studied, for this project, we decided to use an indicator of distance traveled. This is a better predictor of transportation infrastructure needs, as well as a better gauge of overall travel demand. Trip data are also more difficult to obtain and do not necessarily reflect changes in travel demand.

Ideally, we would have liked to have had an indicator of distances traveled for all passengers by each mode because this would cover all facets of personal mobility, but, in reality, this goal was not feasible because of the limitations of available data. As a workable option, we considered four mobility indicators, all measured on a per capita basis: total personal travel on all modes, travel on public transit, nonmotorized travel, and VKT. We also looked at vehicle ownership. Although this is not a direct indicator of mobility, vehicle ownership is often correlated with vehicle travel; those who have access to vehicles tend to make more trips by vehicle than those without (see, for example, Van Acker and Witlox, 2010).

Comparable cross-national data on the first three potential indicators are almost impossible to find. Data for distances traveled by public transit and on nonmotorized modes are difficult to measure except by survey, which has limitations in terms of cross-national comparability and reliability. Many surveys are conducted infrequently or irregularly. There is no universal standard for travel behavior surveys, so individual countries apply varying methodologies to collect the data.<sup>1</sup> Accuracy in personal travel data depends on having data for all modes for all trip lengths, so these limitations on public transit and nonmotorized modes mean that total personal travel cannot be reliably calculated.

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<sup>1</sup> Until the recent advent of global positioning system (GPS) devices, surveys relied on paper-and-pencil travel diaries or respondents' memories about their trips. Both of these have been shown to result in misreporting of travel information, particularly concerning nonvehicle and short trips.

On the other hand, data about VKT are easier to collect via mechanized means. Many countries employ loop detectors embedded in roads to detect the number of vehicles passing over a certain road segment over a given time, and these can be combined statistically to develop an estimate of all travel by vehicles. Others have very good national statistics based on vehicle odometer readings. The downside of this indicator is that it measures only travel by number of vehicles; the detectors or odometer readings do not tell how many occupants are in a given vehicle. So, although helpful as a measure of vehicle travel, it cannot easily be used to measure personal travel.

Vehicle ownership information also tends to be readily available. In most countries, vehicle owners are required to register their vehicles, which creates a set of data about the number of vehicles owned, as well as categories of types of vehicles.

Even where comparable national data sets of VKT and vehicle ownership are available, differences in definitions may remain. However, national data were available for both VKT and vehicle ownership over a long period for our case-study countries, while national travel survey data were not.

We opted to use only one indicator, VKT per capita, as our indicator of mobility. Not only were data more readily available, comparable, and reliable, but VKT captures important trends in automobility. We also collected vehicle ownership data to assist in the selection of case-study countries.

## **GDP as an Indicator of Economic Development**

As noted in Chapter Two, the level of a country's economic development tends to be a strong predictor of mobility. In order to control for the level of economic development to analyze the influence of other factors, we needed to select an indicator of economic development. We decided to use GDP per capita. This is a very common indicator of economic development, despite some criticism that it fails to account for inequality, environmental degradation, and unpaid labor (see Ecola and Wachs, 2012, for a longer discussion of this literature). However, because it is in common use, is easy to calculate, and has a widely understood definition, we opted to use it as our indicator.



## Data Sources and Issues

Initially, we planned to use mobility data available through international sources, such as the International Road Federation (IRF) and ProgTrans for VKT, and IRF, ProgTrans, and the World Bank for vehicle ownership. We hoped that using common sources would reduce the potential problems of assembling data from multiple sources, such as inconsistent definitions. However, in the course of our work, it became apparent that these data sets were unworkable for our purposes for a few reasons. We found that these data

- › were not always internally consistent (for example, some data sets had inexplicable jumps between years that did not reflect normal growth patterns in these indicators)<sup>2</sup>
- › were inaccurate over long periods of time or did not cover sufficiently long time periods
- › did not accurately distinguish between trucks used as personal vehicles and trucks used for movement of goods
- › did not match national statistics or were of unclear origin.

Although none of these data sets would prove to be useful for the later elements of the analysis, we still needed to compare a set of developed countries to select four case-study countries. We also wanted to compare them with the BRIC countries. For the developed-country comparison, we used data compiled by BITRE (2012b). This was published shortly after we began our work. Because it covers several countries of interest, we used it for VKT and vehicle ownership, as shown in Figure 2.1 in Chapter Two. However, this data set does not include the BRIC countries. Therefore, despite their limitations, we used ProgTrans data for those countries and for the 2008 cross-country comparisons in Figures 3.2 and 3.3. Of the international data sources available, ProgTrans included all countries of interest and had the fewest jumps.

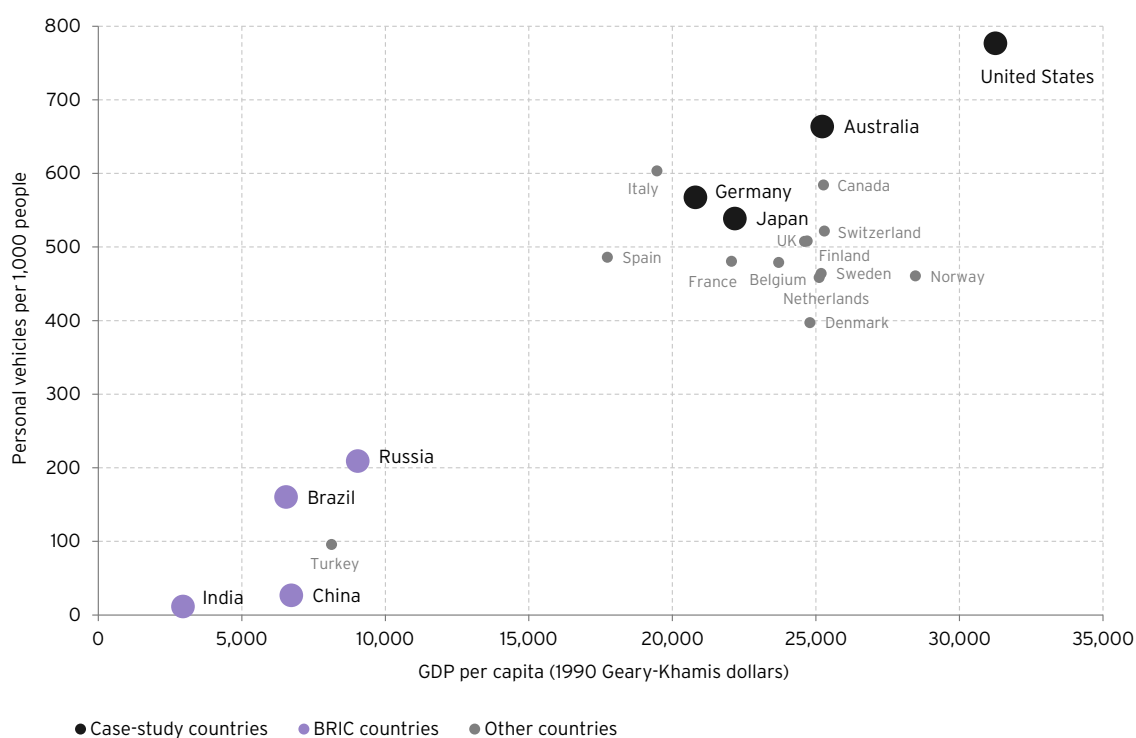
For GDP per capita, we used data from Bolt and van Zanden (2013). These time-series figures, dating back a century or more in some cases, are based on conversion using purchasing power parity (PPP) as opposed to exchange rates. The PPP approach adjusts for the differences in the prices of similar goods and services between countries. These figures, originally developed by Angus Maddison, use a particular conversion developed for international comparisons called Geary-Khamis dollars (unless otherwise noted, all dollar amounts are given in 1990 Geary-Khamis dollars). The strength of these data is that they are not unduly influenced by exchange-rate fluctuations, which can produce GDP per capita figures that are simply not credible. For more technical discussion about conversion, see Appendix A and Maddison (2010b). When this research was being conducted, the data set ended in 2008.

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<sup>2</sup> By jump, we mean a large change in the value of an indicator from one year to the next. Such changes suggest that definitions of the indicator have changed (for example, a change in the definition of personal vehicle) or that they have been combined from multiple data sources that are not consistent.

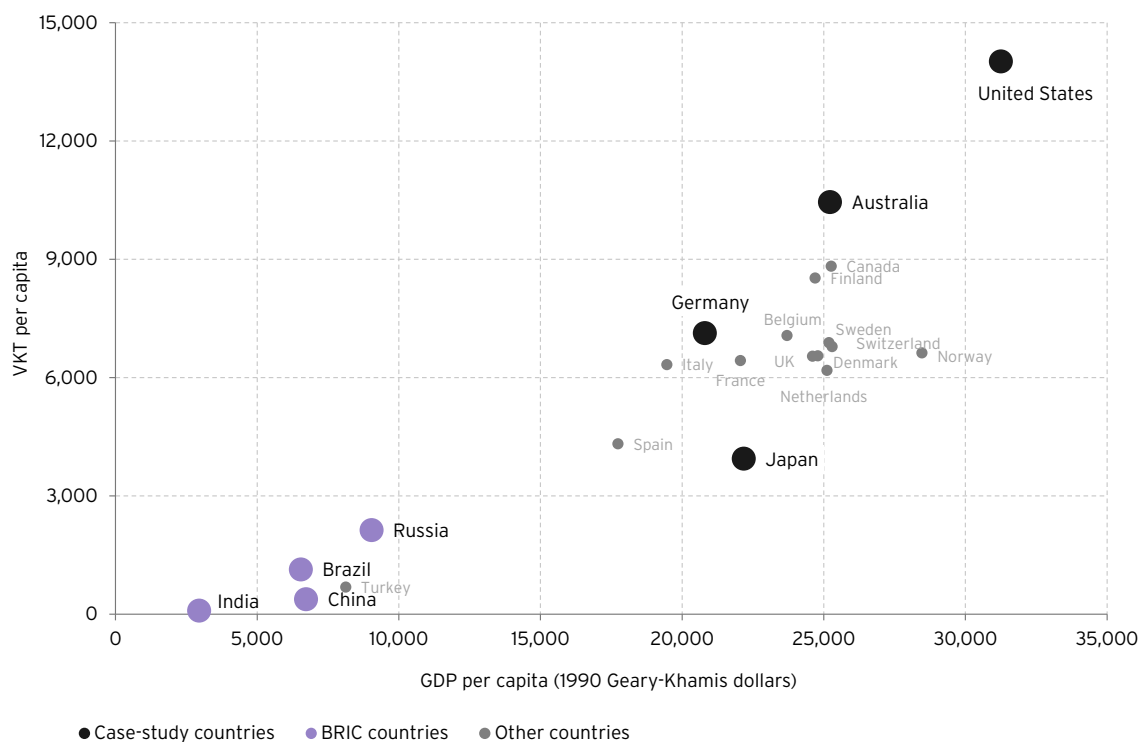
## Selecting Case-Study Countries

Our selection of countries was informed by the need to choose countries in which mobility varies substantially, while keeping the number small for the case-study analysis. To begin this process, we used data for the three indicators to produce scatterplots of multiple countries to determine whether there were shared patterns of mobility. A scatterplot graphs two indicators, one on the x-axis and one on the y-axis, for a single point in time. Because we were interested in differences in mobility once economic development is accounted for, we used GDP per capita on the x-axis. Two key graphs from this analysis are presented in Figures 3.2 (GDP per capita and personal vehicle ownership) and 3.3 (GDP per capita and VKT per capita).



**Figure 3.2. GDP Per Capita and Personal Vehicle Ownership per 1,000 People, 2008**

SOURCES: For vehicle ownership, national data sources (see Appendix A) for OECD case-study countries; Natural Resources Canada, 2010, and Statistics Canada, 2013, for Canada; ProgTrans, 2012, for all others. For GDP per capita, Bolt and van Zanden, 2013.



**Figure 3.3. GDP Per Capita and Vehicle-Kilometers Traveled Per Capita, 2008**

SOURCES: For VKT per capita, national data sources (see Appendix A) for OECD case-study countries; Natural Resources Canada, 2010, and Statistics Canada, 2013, for Canada; ProgTrans, 2012, for all others. For GDP per capita, Bolt and van Zanden, 2013.

It is clear from these figures that, overall, GDP per capita is strongly correlated with both vehicle ownership and VKT. The BRIC countries are clustered in the lower left in both figures because they have low GDP per capita, low rates of vehicle ownership, and relatively few VKT per person. Most of the developed countries are clustered between \$20,000 and \$30,000 GDP per capita. At the top end of the scale, the United States has the highest GDP per capita, the highest vehicle ownership, and the highest rates of VKT per capita. The scatterplots both suggest that GDP has a positive relationship with both vehicle ownership and driving.

However, these patterns are more pronounced in Figure 3.3, which depicts VKT per capita, than in Figure 3.2. If we remove the outliers from each figure (the lower-GDP countries and the United States), the remaining cluster of countries in Figure 3.2 shows a range of about 400 to 650 vehicles per 1,000 people, meaning that, in the country with the highest level of vehicle ownership, people own about two-thirds more vehicles than in the lowest.

In Figure 3.3, VKT per capita in this cluster ranges from 4,000 to almost 10,500, meaning that residents of the highest-VKT country drive more than double the vehicle-kilometers that those in the lowest-VKT country do. Clearly, there are influences beyond GDP per capita that affect vehicle ownership, but even more so for driving. This much larger range of outcomes led to our decision to focus on VKT.

Other research analyzing these relationships confirms these patterns. Millard-Ball and Schipper (2011) developed graphs (similar to Figure 2.1 in Chapter Two) of eight countries, using GDP per capita and all motorized travel. They found a clear pattern of four clusters, with very similar patterns in the four European countries that they studied (France, Germany, Sweden, and the United Kingdom). Canada and Australia were in another cluster, and both the United States and Japan were dissimilar to any other country. Dargay, Gately, and Sommer (2007, Figure 1) depicts similar graphs for vehicle ownership (instead of motorized travel) for the United States, Germany, Japan, and South Korea, and all follow similar trajectories from 1960 to 2002.

For our case-study analysis, we selected the two countries on the extremes of automobility, the United States and Japan. In 2008, Americans owned about 775 personal vehicles per 1,000 people, and Japanese owned 535. The gap was even wider for VKT: Americans drove about 14,000 km per year, while Japanese drove less than 4,000. Given these large disparities, it seems that these represent two very different evolutionary paths of mobility.

As shown in Figures 3.2 and 3.3, the rest of the developed countries analyzed fall in a relatively large cluster on both indicators (Turkey more closely resembles the BRIC countries). From these 12 countries, we decided to select Australia and Germany. Our choice of Australia was based on some similarities to the United States—both are geographically large with more recent histories of settlement than the European countries—yet Australia has substantially lower rates of vehicle ownership and driving. We hoped that the selection of two large countries would, to some extent, control for geographic size in our analysis. The BRIC countries are all geographically large as well; these six countries are among the seven largest countries in the world in terms of area.

Finally, we wanted to use a European country because both our analysis and Millard-Ball and Schipper found a European cluster. Germany falls in the middle of this European cluster in both indicators, so it represents a typical and not an outlying path for European mobility development.

The data sets for the four case-study countries in Figures 3.2 and 3.3 were developed from national sources after the case-study selection was completed. This was due to the need for longer time series and more accurate definitions of the key indicators. For example, it was not always clear from international sources what was considered a vehicle. Also, to measure passenger travel, we had to exclude travel for commercial purposes (that is, movement of goods via truck). Although this seems straightforward, the definitions of car and truck have overlapped in many countries as households have purchased vehicles for personal use that are generally classified as trucks (such as sport-utility vehicles and pickup trucks). Further details on those data are provided in Appendix A.

We used a less analytical approach for the selection of developing countries. The BRIC countries are all large developing countries with the potential to contribute significantly to global carbon emissions and markets for automobile ownership (China is currently the world's largest producer and purchaser of cars). We wanted to include China and India because they are the two largest countries in the world in terms of population. Russia and Brazil have the highest per capita incomes among developing countries with populations greater than 100 million. Because these countries are developing rapidly, they have garnered intense interest in their future rates of motorization and travel demand. Together, these eight study countries represent about half of the world population.

## Selecting Factors That Affect Automobility

We then used a multistep approach to identify the key factors, outside of GDP per capita, that have affected mobility development in Australia, Germany, Japan, and the United States. We define factor as an exogenous element contributing to a particular outcome. We know that GDP per capita is a factor that affects mobility; in this phase of the project, the goal was to identify other key factors.

Our first step was to review existing literature for evidence on the factors that are commonly thought to influence mobility. We used a three-pronged approach for identifying relevant articles to ensure that key studies on the subject were captured:

- › First, we compiled a list of relevant articles already known to the research team at the start of the study.
- › Second, we undertook a wider systematic search in two bibliographic databases: Transport Research International Documentation (TRID) and ScienceDirect.<sup>3</sup>
- › Finally, we reviewed the bibliographies of relevant papers to identify additional academic and nonacademic articles. (All documents reviewed for this phase of the work are listed in "References" at the end of this report.)

This approach yielded one list of factors. Although these were valuable, the search also revealed some of the difficulties in identifying appropriate factors. For example, much work in this area is on mobility at the city, not country, level. Also, most future-oriented studies focus exclusively on income as a predictor.

The second step was to develop historical case studies of the four developed countries. For each country, we reviewed literature on the evolution of mobility and wrote a case study tracing developments in mobility back to the 19th century. Because we attempted to capture a long history, the case studies did not analyze trends in detail, but we included discussion of such topics as the emergence of railroads and vehicle ownership; national policies regarding transportation, such as road or public transport infrastructure prioritization; long-term demographic and urbanization trends; and turning points, such as World War II. The case studies form the basis of the discussions in Chapter Four.

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<sup>3</sup> The TRID database integrates the content of two major databases: OECD's Joint Transport Research Centre's International Transport Research Documentation (ITRD) database and the Transportation Research Board's (TRB's) Transportation Research Information Services (TRIS) database. TRID indexes more than 900,000 records of transportation research worldwide. ScienceDirect is an information source for physical sciences and engineering, life sciences, health sciences, and social sciences and humanities. The database covers 3,300 journals and book series.

The third step was deriving hypotheses from the case studies about which factors seemed to have specific effects on mobility. After reading the case studies, the team members individually developed lists of hypotheses that linked a factor with a mobility outcome. For example, one hypothesis was that low gasoline prices during the era of motorization encourage high continuing levels of vehicle ownership because people purchase and become reliant on cars when they are inexpensive and then have difficulty transitioning to other modes. We developed a master list of these hypotheses and, from that, culled a separate list of factors.

A fourth step was to solicit input from experts representing our study countries. We provided these experts the preliminary list of factors and asked them to rate the importance of these factors in terms of shaping automobility development. In addition, the experts were asked to identify any other factors that they deemed important. The final step to refine this list was qualitative. The research team assessed each of the initial factors against a set of criteria:

- › To keep the analysis manageable, the list should include nine or ten factors.
- › The list should focus on factors that influence both vehicle ownership and VKT (because we were conducting some research steps simultaneously, we were still considering other mobility indicators during factor development).
- › The list should not include factors that
  - are difficult to measure or operationalize
  - seem less relevant to developing countries than to developed ones
  - would have minimal explanatory power compared with other factors
  - overlap too much with other factors.

Using these criteria, we developed a list of nine factors, shown in Table 3.1. The factors were defined such that an increase in the level of the factor was hypothesized to lead to an increase in one or both mobility indicators. In some cases, we combined multiple factors identified in the steps into a single factor; for example, population density, level of urbanization, and size of cities are all covered under “spatial dispersion.”

We also divided the factors into two broad categories: exogenous and transportation policy factors. Exogenous factors are those that transportation policymakers cannot change or over which they have very limited control. For example, whether a country has a strong domestic car industry depends on variables ranging from historical precedent to a skilled workforce to industrial policy. Transportation policy factors, in contrast, are those that are directly affected by transportation policymakers. Whether fuel is inexpensive is largely a function of taxation levels, which can be changed through policy.

We recognize that these categories have some overlap. However, we thought that it was important to distinguish between factors that are largely external to transportation and those that are within the purview of transportation officials, at least to some extent, to help to assess the role of policymaking on mobility paths. The exogenous factors provide the background within which automobility occurs, and the transportation policy factors help shape automobility more directly.

Table 3.1. Final List of Factors Influencing Mobility, with Definitions

FACTOR	DEFINITION
<b>Transportation policy</b>	
Good car infrastructure	All infrastructure for driving, including the quality and quantity of roads, parking, and level of service
Inexpensive fuel	Whether the price of fuel (including taxes) is inexpensive relative to income
Pro-car policies	All noninfrastructure policies and regulations on car ownership and usage, including vehicle costs (e.g., registration fees), regulations (e.g., driving restrictions), and specific policies (e.g., “cash for clunkers”)
Lack of alternatives to driving	How car-focused the transport supply in a country is vis-à-vis the infrastructure for alternative modes for urban and interurban travel
<b>Exogenous</b>	
Active population	The share of the population in a life stage characterized by high mobility rates; includes both demography effects (i.e., age classes in which mobility is typically high) and workforce participation (i.e., the share of the working-age population who are employed)
Existence of domestic oil	Availability of domestic oil, its relevance to the national economy and politics; having domestic oil does not necessarily result in energy independence
Strength of the domestic car industry	Existence of a domestic car industry and its relevance to the national economy and politics
Spatial dispersion	The extent to which settlement patterns are conducive to automobility. This includes (1) how many people live outside urban areas or centers of population and (2) the degree of low-density urban development, including the densities (e.g., population, jobs) of cities of all sizes.
Favorability of car culture	Whether there is an overall cultural environment (including popular culture, attitudes toward the environment, consumer attitudes, and perceptions) that favors cars and driving over other modes

Two factors we discussed at length but ultimately decided not to use are technology and geographic size. New technology can potentially encourage mobility by making travel faster or easier. For example, the advent of autonomous vehicles may make driving less onerous for drivers, and drivers may drive longer distances as a result. Additionally, for the “less active population” (the young, the elderly, and the disabled), travel in private vehicles independently and on their own schedule may also become possible, thus increasing their mobility (J. Anderson et al., 2014). Although we have good reasons to believe that such technological changes may affect the eventual saturation levels, they will likely affect the developed and developing countries differently because of the cost and diffusion of the technologies.

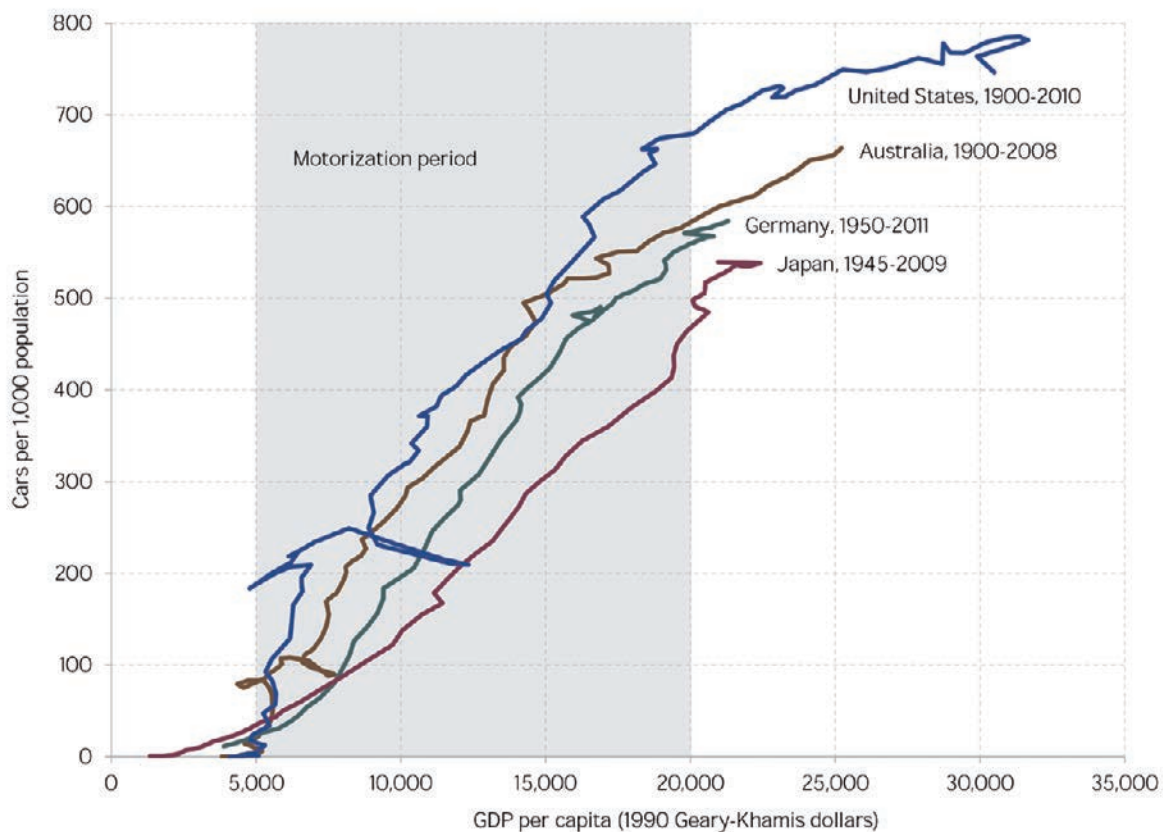
With regard to geographic size, we recognize that size may play an important role in the development of mobility because small and large countries, by nature, have to think differently about how to allocate land between rural and urban uses. Obviously, large countries have much longer internal travel distances as well. The former of these is probably more important to this study because we are primarily concerned with daily mobility rather than long-distance travel. But we felt that the spatial-dispersion factor captured the strength of urbanization more than size alone did and that spatial dispersion has a more direct impact than size. In addition, all four of the BRIC countries are quite large, so this factor will not vary much between them.

## Estimating Impacts of Factors on Mobility

Our next step was to operationalize how these factors affect mobility, based on the experiences of the case-study countries. To do this, we needed to define the temporal boundaries during which the individual countries’ mobility paths evolved. Choosing the same study period for all OECD countries (e.g., 1950-2000) would not do justice to the substantial differences in the speed of economic development and motorization in these countries. We needed to select the appropriate motorization period for each country.

To help define the motorization period, we developed Figure 3.4, which shows motorization rates (personal vehicles per 1,000 people) by GDP per capita, based on data sets compiled from each country’s national statistics (details in Appendix A). This represents the longest possible time series for each country; pre-World War II vehicle ownership data for Germany and Japan were not available.





**Figure 3.4. Motorization Rates and GDP Per Capita Growth for OECD Study Countries**

SOURCES: For GDP per capita, Bolt and van Zanden, 2013. For personal vehicle ownership, see Appendix A for individual country sources.

In line with other research (such as Dargay, Gately, and Sommer, 2007) and informed by the data presented in Figure 3.4, we concluded that the period of intermediate economic development is key to the evolution of automobility in the study countries. At very low levels of GDP per capita (generally, below \$5,000), personal vehicles are affordable only to small, affluent segments of the population, and differences in automobility across countries are very slight. At relatively high levels of GDP (typically, above \$20,000), personal vehicles are generally affordable to large segments of the population, and differences across countries in terms of automobility are evident. These differences evolved during the intervening decades of intermediate economic development, as per capita incomes rose. So we defined the relevant study period—the motorization period—as beginning in the decade in which GDP per capita reached \$5,000 and ending in the decade in which it reached \$20,000.<sup>4</sup>

<sup>4</sup> Obviously, this assumes that GDP per capita continually increases, which is generally but not always true for developed countries in the 20th century. This is the main reason that we identified decades rather than specific years. In reviewing the patterns of GDP per capita for each OECD country, we selected the decade in which GDP per capita rose to this level and did not subsequently fall well below it. For example, U.S. GDP per capita fell briefly below \$5,000 during the Great Depression of the 1930s, but for only two years before continuing its upward trajectory.

This definition was based partly on empirical evidence and partly on practical considerations. On the one hand, we needed historical data for the time when the OECD study countries surpassed the lower limit. (Information on GDP per capita was available back to 1900 for all OECD countries in Bolt and van Zanden, 2013; no country had a per capita GDP of more than \$5,000 in 1900.) On the other hand, to avoid having to estimate the situation many decades from now, we needed an income level that the BRIC countries have recently reached or will reach soon. The United States passed this lower threshold (\$5,000) in the first decade of the 20th century, and India is likely to pass it within the next decade.<sup>5</sup> For the upper limit, Figure 3.4 shows that the motorization curve is fairly steep during this period, albeit not identical for every country. So the length of the motorization period, along with its start and end points, varies from country to country, depending on the country's income levels.

Using these start and end points, we defined three indicators:

- › **Factor scores** quantify the state of each factor in the country. We defined each factor along a spectrum of -2 to 2, such that all factors were aligned in the same direction. That is, a score of -2 correlates with low auto mobility, and 2 with high automobility. In the case of the OECD study countries, the factor scores describe historical conditions at the start and end points of the motorization period. For the BRIC study countries, the factor scores describe forecasted future conditions during the next decades, when the countries are expected to reach these income levels.
- › **Factor weights** describe how strongly each factor influences automobility. Unlike the factor scores, which vary from country to country, we developed one set of factor weights for both the OECD study countries and the BRIC countries. Factor weights are designed to capture the general influence of the factors on automobility, so the weights are the same across all countries. Factor weights are on a scale of 1 to 3, where a 3 represents the greatest impact.
- › **Automobility scores** combine a country's factor scores with factor weights into a single number that describes how conducive the overall environment is to automobility. The higher the score, the more likely the country has or will have high rates of personal vehicle travel. If the automobility scores accurately describe a country's propensity for personal vehicle travel, they should—for the OECD study countries—show a good correlation with the long-term evolution of automobility. In turn, forecasted automobility scores for the BRIC countries should reliably suggest the ultimate saturation level of personal vehicle travel.

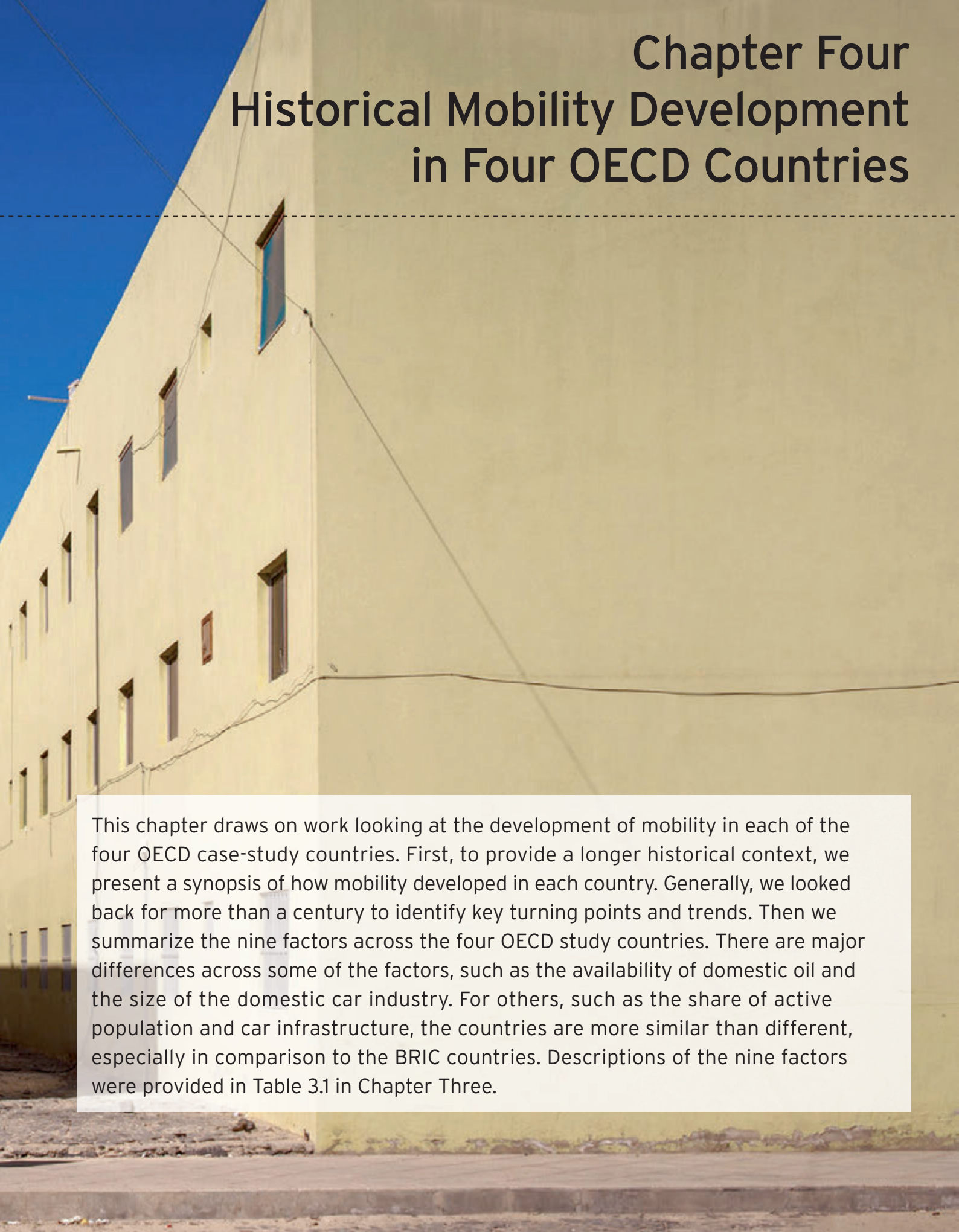
<sup>5</sup>To arrive at estimates about future decades during which an individual BRIC country would pass the respective GDP per capita thresholds, we presented long-term GDP forecasts (PPP adjusted) to our country experts and discussed these with them at the workshop. These GDP forecasts were generated by extrapolating the existing database of Bolt and van Zanden (2013) (GDP in 1990 Geary-Khamis dollars up to 2010) using future year-on-year GDP changes derived from GDP forecasts made by a private company, IHS Global Insight, through 2043. This subscription-only Global Insight database was made available to ifmo through the BMW Strategy Department. In most cases, the country experts approved the GDP forecasts. In the case of China, the forecast was deemed too optimistic, so China's reaching the \$20,000 was postponed into the future and the study period was extended accordingly. The result was that Brazil, China, and Russia would reach the \$20,000 threshold in the 2030s, while India would reach it in the 2040s.

To develop the first two indicators, we conducted a two-day face-to-face workshop with travel behavior experts from all eight case-study countries. The workshop was held in Berlin in April 2013; a list of experts and their affiliations is provided in Appendix B. Prior to the workshop, we provided the experts with definitions of the factors and background information on the factors in the OECD case-study countries. During the workshop, we asked the experts to provide factor scores for each case-study country at the beginning and end of the motorization period. We began by asking the experts from each BRIC country to comment on their own countries, but the entire group then discussed the factor scores. Factor weights were established in a general discussion. After these scores and weights were tabulated, along with the automobility scores, the team asked the experts to validate them in a postworkshop round via email.

The last step was to develop two models. The first model estimates the saturation level in the four OECD countries, using an S-curve fitted to long-term data on GDP per capita and VKT per capita. We developed a separate model, using a Gompertz function, for each of the four countries. The second model uses regression analysis to determine whether the automobility scores of the OECD countries are good predictors of the saturation levels. This model determined that they are. Informed by this result, we used the automobility scores to forecast the saturation levels of the BRIC countries. These are presented in Chapter Six. More details on the modeling are provided in Appendix D.







# Chapter Four Historical Mobility Development in Four OECD Countries

This chapter draws on work looking at the development of mobility in each of the four OECD case-study countries. First, to provide a longer historical context, we present a synopsis of how mobility developed in each country. Generally, we looked back for more than a century to identify key turning points and trends. Then we summarize the nine factors across the four OECD study countries. There are major differences across some of the factors, such as the availability of domestic oil and the size of the domestic car industry. For others, such as the share of active population and car infrastructure, the countries are more similar than different, especially in comparison to the BRIC countries. Descriptions of the nine factors were provided in Table 3.1 in Chapter Three.

## Country Profiles

In this section, we present a very brief synopsis of the development of transportation in each of the four OECD case-study countries. Obviously, these synopses cannot cover all the important aspects of a century's worth of mobility development; the goal is to present a snapshot comparison that highlights how the four case-study countries have differed in their evolutionary paths.

### Australia

In Australia, personal vehicle ownership and travel are fairly high (about 650 vehicles per 1,000 people and more than 10,000 VKT per capita), but not at the level of those in the United States, which is similar in many regards. Until federation in 1901, there was very little coordination among the various colonies to provide infrastructure (Australia Department of Infrastructure and Regional Development, undated). Many roads were in poor condition when railroads were introduced in the 1850s, and a lack of funding meant that many roads declined in quality. From about 1880 to 1930, rail was the dominant mode, with roads and tram services often built to serve the rail network (Australian Bureau of Statistics, 1974).

In the 1920s, Australians began buying cars in large numbers; vehicle ownership per 1,000 people rose from two in 1920 to ten in 1930. A key reason was declining prices; prior to 1920, cars typically cost several times the annual minimum adult male wage, but, by 1925, a new car could be purchased for less than a year's pay (Knott, 2000). Cars were popular in rural areas, where distances to the nearest town were long. Transit ridership began declining during this period as well.

Road building picked up in the 1920s in response to demand. During World War II, some important arterials roads were constructed to further the war efforts; on the other hand, rural roads were neglected. In 1947, the Commonwealth Aid Roads and Works Act provided funding specifically to restore the rural road network.

After World War II, Australian cities spread out. This suburbanization was fostered by the War Service Homes Scheme, which financed land ownership and detached dwellings for returning servicemen, and by state and federal funding that facilitated the development of urban freeways (Falconer, Giles-Corti, and Lyons, 2007). Many cities dismantled tram systems and replaced them with buses. Levels of investment in public transport projects were significantly lower than those in the highway system. Vehicle ownership and travel grew rapidly from World War II through about 1980, driven by rapidly rising incomes and the associated trend of higher female workforce participation and facilitated by low fuel prices.

Australia was relatively slow to involve the national government in transportation infrastructure provision. Only in 1974 was the National Roads Act adopted, under which the national government agreed to plan and fund a coordinated system of national highways.

VKT per capita has declined over the past decade, from about 10,375 to 10,135. Contributing factors seem to include the deregulation of domestically produced oil prices in 1978, which made fuel more expensive; the aging of the population; and the tendency for young adults to delay obtaining driver's licenses. The last of these may be due in part to the introduction of graduated driver's licenses, meaning that a new driver receives a limited license in his or her teens and a full license only after several years of driving experience. Australia was the first country to adopt such programs.



## Germany

Germany represents a typical European path of mobility, with a high level of economic development and moderate levels of vehicle ownership and driving. Before the turn of the 20th century, Germany had an established railroad network but a fairly poor road system. Urban rail systems were introduced in the early 1900s. Although much early work on automotive technology was carried out in Germany, the German auto industry was one of the smallest in Europe before World War II (Overy, 1975).

Vehicle ownership was relatively low through the 1920s. Poverty and hyperinflation following defeat in World War I were one reason (Vahrenkamp, 2012); in addition, cars carried a federal luxury tax (Overy, 1975). However, in the late 1920s, the tax was repealed and vehicle prices fell, ushering in higher levels of vehicle ownership, albeit still low compared with those in other European countries. In the early 1930s, road building was used heavily as an economic development policy. The first autobahn opened in 1932, and about 60 percent of all public investment was directed to transportation, mostly to roads, between 1933 and 1935 (Overy, 1975).

World War II not only left much infrastructure damaged or destroyed; it also resulted in Germany's division into West and East. West Germany absorbed high numbers of refugees, which initially increased densities but, in the 1950s, led to the construction of new neighborhoods at lower densities. Incomes and vehicle ownership grew; personal vehicle ownership per 1,000 people increased sixfold from 12 in 1950 to 80 in 1960 (Pucher, 1998) and then to 230 by 1970. West Germany also instituted a fuel tax and invested its substantial revenues in both roads and transit systems. Transit ridership reversed its decline due in part to transport associations, whose goal was to improve transit integration, and many cities introduced traffic-calming measures.

In the meantime, East Germany remained poorer, and vehicle ownership remained much lower. Policies discouraged vehicle ownership and promoted transit use. By the time of reunification in 1990, West Germans owned 482 vehicles per 1,000 people, while East Germans owned 237 (Buehler, 2008; Federal Ministry of Transport, Building and Urban Development, 1991). Reunification brought the challenge of reintegrating the country's infrastructure; the massive Unity Transport Projects program paid for infrastructure upgrades in the East but also improved East-West connectivity. The Federal Transport Infrastructure Plan earmarked around 454 billion deutschemarks (approximately \$270 billion at 1992 rates) for rail, road, and waterway infrastructure from 1992 to 2012 (Wissmann, 1994).

Postunification, the East has become more like the West in terms of vehicle ownership and use of driving over transit. However, high fuel taxes and parking costs have led to modest increases in transit use throughout Germany. Another recent trend has been declining vehicle ownership, licensing, and vehicle travel among young adults (Kuhnimhof, Buehler, Wirtz, et al., 2012).

## Japan

Japan represents a path of high personal income but relatively low vehicle travel per person. In the mid-1800s, when Japan was a largely feudal state, there was a very limited road network and no rail; people traveled on foot or horseback, and goods were moved by water. The situation changed abruptly after the Meiji Restoration ended the feudal era in 1868, and Japanese leaders rushed to catch up with the west in terms of technology.

As rail was the dominant mode in the west, Japan poured considerable resources into creating a rail network, largely skipping the horse-drawn-vehicle stage. The goal, largely achieved, was to adopt and build on technologies developed elsewhere. The important Tokyo-Kyoto route opened in 1889; from 1889 to 1893, the total length of railways grew from 1,720 km to 3,010 km (Aoki, 1993a). Rail was not limited to intercity travel; in the 1910s and 1920s, the population urbanized rapidly, and most major cities constructed urban and suburban rail lines.

Cars were not widespread in the early 20th century; as late as 1930, there were 57,000 vehicles (H. Yamamoto, 1993) in a country of almost 65 million people. However, trucks and buses gained popularity, and national road-building standards adopted in 1926 finally acknowledged the need to accommodate motorized vehicles (H. Yamamoto, 1993). During World War II, supplies of gasoline and civilian travel were both limited, and the transportation infrastructure sustained severe damage. Under the postwar occupation, led by an American general, official policy was to limit reindustrialization, but rebuilding of roads and rail rolling stock was allowed.

After the occupation ended in 1951, the Japanese government again turned to a foreign technology to develop economically: automotive manufacturing. Auto manufacturers were eligible for tax advantages and low-cost government loans. They responded by developing small, reliable, affordable vehicles, inspired by the government's People's Car Plan of 1955 (Japan Automobile Manufacturers Association [JAMA], undated). By 1967, Japan was producing almost 2.3 million vehicles (JAMA, 2011), making it the world's second-largest producer of cars (JAMA, undated). During the same period, both incomes and auto ownership expanded rapidly; by 1973, 33.5 million vehicles were registered (JAMA, 2011). The country's increasing prosperity led to much-needed major infrastructure improvements. As late as 1956, only 2 percent of all roads were paved (JAMA, undated). A massive road-building program absorbed 40 percent of all government public works spending in the 1960s and 1970s (JAMA, undated). The world's first high-speed train began service in 1964, and urban rail systems were expanded and modernized.

In 1973, the oil shock hit Japan hard; without domestic oil supplies, Japan had imported about 80 percent of its oil from the Middle East. One response was to begin manufacturing more fuel-efficient vehicles, which paved the way into the lucrative U.S. market. Although the Japanese auto industry remains important, driving and vehicle ownership have leveled off and even declined, perhaps due in part to a relatively sluggish economy during the past two decades, a rapidly aging population, and the high cost of owning and driving cars.

## United States

The history of transportation in the United States is one of early and extensive motorization. Railroads dominated interurban transportation in the 1850s through 1880s, while previous toll roads were falling into decline. American cities experienced enormous growth in the 1880s and 1890s; when streetcars were introduced in the late 1890s, they spread rapidly, facilitating suburban growth.

After the successful creation of a mass-produced car in 1900, American car ownership increased enormously, rising from 450,000 vehicles in 1910 to 23 million in 1930 (Federal Highway Administration [FHWA], 1995). Although many early vehicles were electric, the discovery of major oil fields in two U.S. regions helped cement the dominance of gasoline-powered vehicles. Oil prices remained low during this period, making travel by car more affordable than other modes. The demand for roads grew with the demand for vehicles, both of which furthered the trend of suburbanization.

After World War II, the United States was the world's dominant economic power, in part because of the strength of its automobile manufacturing industry. Car ownership continued to grow, the federal interstate system was signed into law in 1956, and gas prices remained low (in current dollars, gas remained under \$0.50 per gallon from the 1920s through the early 1970s [Vehicle Technologies Office, 2005]). As residences shifted to suburban locations (by the 1960s, more than half of new housing units were built in the suburbs [Williams, 2004]), employment and retail followed, creating many neighborhoods where transportation was all but impossible without a private vehicle. Transit ridership began a long, slow decline from its peak during World War II, and many streetcar systems were replaced with bus lines.

The Arab oil embargo in 1973 was a major shock to the United States, long accustomed to plentiful and inexpensive gasoline. It had several long-term repercussions: The federal government introduced its first set of fuel-economy standards, the American auto industry faltered in the face of high demand for higher-efficiency vehicles, and oil prices not only increased but also became more volatile. But, as prices leveled off in the 1980s, light trucks gained popularity as personal vehicles, in part because they were exempt from fuel-economy standards. The number of VKT continued to grow in the 1980s and 1990s as well, due in part to suburbanization but also the widespread entry of women into the workforce.

Although vehicle ownership and vehicular travel remain the highest in the world, some of these trends have been tempered recently. Both have not only leveled off but also declined since the mid-2000s, which pre-dates the recession of 2008 and suggests that other factors are at work. Some cities have adopted changes in planning and zoning regulations that encourage transit ridership and walking and bicycling, and new forms of mobility, such as bike- and car-sharing, have found a small but growing base of users.





# Chapter Five

## Comparison of Factors Among the Four OECD Countries

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In this chapter, we describe how each of the nine factors has played out in the four OECD countries during the motorization period. Both quantitative and qualitative data sources were used, and, where possible, the same data sources are used for all four countries. The discussion begins with the four transportation policy factors, then moves to the exogenous factors. The chapter is illustrated with some of the data presented at the workshop, but much information is qualitative and did not lend itself to comparison graphics.



**EXISTENCE OF  
DOMESTIC OIL**



**INEXPENSIVE  
FUEL**



**STRENGTH OF  
THE DOMESTIC CAR  
INDUSTRY**



**GOOD CAR  
INFRASTRUCTURE**





**ACTIVE  
POPULATION**



**LACK OF  
ALTERNATIVES TO  
DRIVING**



**PRO-CAR POLICIES**



**FAVORABILITY OF  
CAR CULTURE**



**SPATIAL DISPERSION**

## Good Car Infrastructure

Car infrastructure refers to the state of the country's roadways, looking at both the quantity (in center-line kilometers) and quality of roads. All figures on the length of center-line kilometers of road are from The World Factbook (Central Intelligence Agency [CIA], undated).<sup>1</sup> Certainly in terms of the sheer volume (again in center-line kilometers) of roads, geographic size is probably the largest determinant; the United States and Australia have far more kilometers per inhabitant than Germany and Japan. All four countries now have well-maintained infrastructure, but they developed at different points in time. Australia has a high percentage of unpaved roads.

### Australia

Although Australia has an extensive road network, it was slow to develop and remains less modern than those in other countries. During the colonial period in the 1800s, roads were relatively few and in generally poor condition. When railways were introduced in the 1860s, they were seen as a far superior means of long-distance travel, and, as road tolls were eliminated, road conditions worsened because of lack of funding. Road conditions did not improve until motor vehicles began gaining popularity in the 1920s; at the same time, the states began establishing road departments to guide construction. During World War II, some roads were improved for military purposes, while others deteriorated; after the war, the national government assisted the states with rebuilding (Australian Bureau of Statistics, 1974). However, a system of national highways, now called the AusLink Network, was not established until 1974 (Australia Department of Infrastructure and Regional Development, undated). Currently, Australia has about 823,000 km of roads, or 37 km per 1,000 people. Australia also has a far lower percentage of its roads paved than other developed countries, with less than 45 percent of total kilometers paved (World Bank, 2013).

### Germany

Germany has had three main waves of road building. The first took place beginning in the 1930s, when the government laid the foundation of the motorway network. About 60 percent of all public investment was directed to transportation, mostly to roads, between 1933 and 1935 (Overy, 1975). The first autobahn from Bonn to Cologne opened in 1932, and others soon followed (Vahrenkamp, 2012). The second was after Germany was partitioned following World War II, when West Germany invested massively in road infrastructure. Finally, reunification prompted a huge investment through the German Unity Transport Projects program (Verkehrsprojekte Deutsche Einheit). This paid for infrastructure upgrades in the previous East Germany but also improved East-West connectivity. Currently, Germany has a roadway network of about 645,000 km, or 8 km per 1,000 people.

<sup>1</sup> Road length can be measured in two ways: the number of center-line kilometers, meaning the total length of a road corridor, and the number of lane kilometers, which is the number of center-line kilometers multiplied by the number of lanes. The World Factbook (CIA, undated) includes both paved and unpaved roads.

## Japan

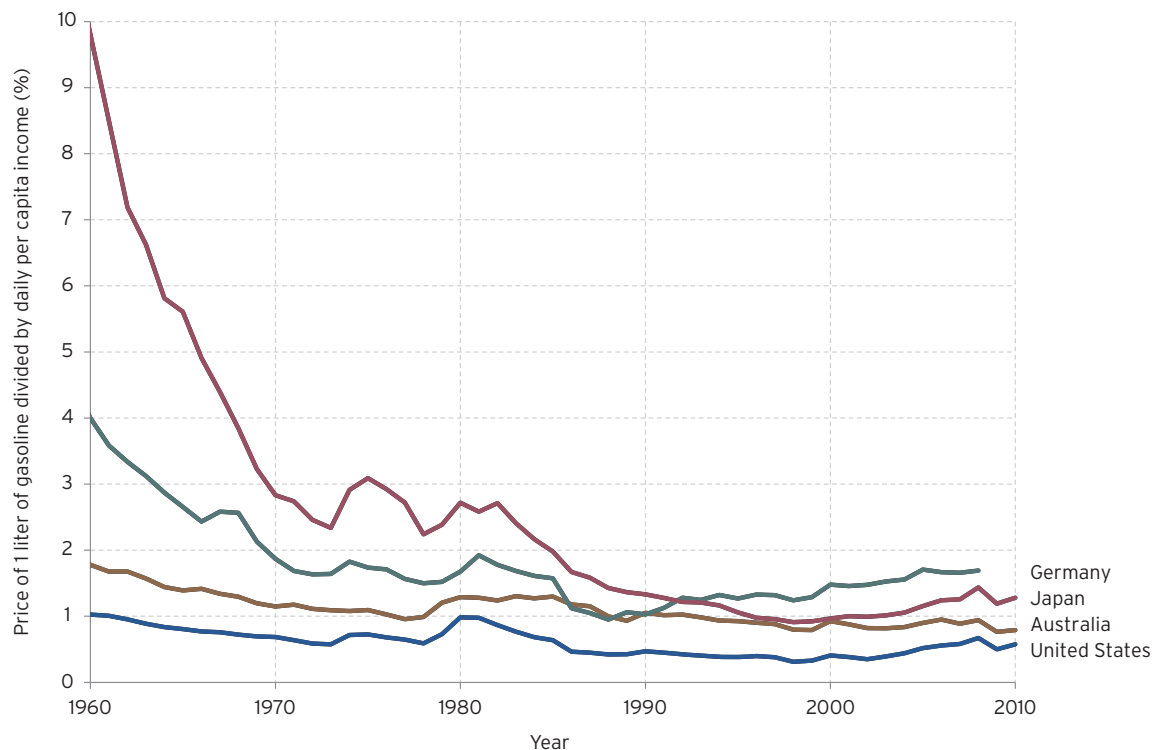
Japan was relatively late to road construction. In the 1800s, the country essentially skipped the horse-drawn-vehicle stage that prompted road building in other countries and went directly to building rail in the name of modernization (Hayashi, 1990). Although some roads were built before the war, much transportation infrastructure was destroyed during World War II. As late as 1956, only 2 percent of the country's roads were paved (JAMA, undated). The Japan Highway Public Corporation was created to facilitate the construction of major trunk roads and toll roads. Japan also began earmarking road-use fees, such as fuel tax revenue, to embark on road construction and improvement, and the World Bank provided funding to construct expressways in time for the 1964 Tokyo Olympics (Kojima, Goto, and Kato, 2012). The needs were so great that, in the 1960s and 1970s, road building absorbed 40 percent of all government public works spending (JAMA, undated). Today, Japan has about 1.2 million km of roads, the fifth-largest network in the world, but only 9 km per 1,000 people.

## United States

In the United States, the demand for paved roads dates back to the 1880s. Many rural roads were unpaved and nearly impassible, and bicyclists rallied behind the "good roads" movement to advocate for paved roads. The U.S. government's first agency for road construction was formed in 1905 (FHWA, 1977). As vehicle ownership grew in the 1910s and 1920s, road building grew apace. Another major set of investments in roads took place in the 1950s and 1960s, after a national law mandated a system of highways connecting the entire country. Relatively little new roadway capacity has been created since 1970; the number of center-line miles has increased less than 10 percent since then (Bureau of Transportation Statistics [BTS], undated, Table 1-1). Currently, the United States has roughly 6.5 million center-line kilometers of roads—the longest roadway network in the world—and 21 km of center-line roads per 1,000 people. In addition, the majority of workplaces have free parking, as do many other destinations. According to one estimate, 91 percent of American commuters drive to work, and 95 percent of them have free parking (Shoup, 2005).

## Inexpensive Fuel

To capture some measure of how expensive or inexpensive fuel is in a particular country, this factor considers the cost of fuel relative to per capita GDP. In a data series that we compiled for all countries,<sup>2</sup> the four OECD countries currently all enjoy low fuel costs relative to income, with the price of 1 liter of gasoline ranging between about 0.7 to 1.75 percent of average GDP per capita per day (Figure 5.1). The current price of 1 liter of gasoline ranges from \$0.97 in the United States to \$2.12 in Germany (“Pain at the Pump,” undated). Although oil prices are generally determined on the world market, national and subnational taxes can increase the price considerably. The percentage of “at-the-pump” fuel price that is composed of taxes ranges from a low of 18 percent in the United States to a high of 62 percent in Germany (BITRE, 2012b, Appendix A, Per Cent Tax Table).



**Figure 5.2. Price for 1 liter of Gasoline as a Percentage of Average Daily Income (Gross Domestic Product Per Capita per Day)**

SOURCE: See Appendix A.

<sup>2</sup> For each country, we derived fuel prices from national sources and compared them with GDP figures. See Appendix A for specific sources.

## Australia

As a fuel-producing country, Australia kept oil prices regulated and fairly low through 1978. Deregulation began in 1978 and was fully implemented by 1985. Between 1970 and 1985, domestic prices were lower than the equivalent market price, differing by up to \$0.15 or more per liter (in 1989-1990 Australian dollars), but, subsequently, they have tracked very closely (BITRE, 2012a, Figure 1.2). As of 2010, fuel taxes make up about 40 percent of the cost of gasoline (BITRE, 2012b, Appendix A, Per Cent Tax Table).

## Germany

In the early 1950s, gasoline was relatively expensive in Germany; the cost of 1 liter was more than 25 percent of daily income. This ratio fell rapidly through the early 1970s because of rapid economic development, not decreases in nominal fuel cost. The environmental goals that were part of the German Unity Transport Projects program ushered in a period of very high fuel taxation in Germany. From 1960 to 2005, the share of taxes in the price of gasoline increased from 60 percent to 70 percent (Buehler, 2008), although it has since fallen to 62 percent (BITRE, 2012b, Appendix A, Per Cent Tax Table). Fuel tax contributed to general revenue and to lowering social security taxes (Buehler, 2008). As of 2010, 1 liter of gasoline cost \$1.87 (in 2010 U.S. dollars) (BITRE, 2012b, Appendix A, Real Petrol Prices Table). Diesel prices are considerably lower than those for gasoline, which has increased the preference for diesel cars (Kalinowska and Kuhfeld, 2006).

## Japan

In 2010, the tax share in gasoline cost was about 50 percent (BITRE, 2012b, Appendix A, Per Cent Tax Table). Of the four OECD countries, Japan has experienced the greatest postwar decline in relative fuel prices. In the early 1950s, the cost of 1 liter of fuel represented nearly 15 percent of average daily income, but, by 2010, it was about 1.25 percent. The share of taxes as a percentage of fuel price was about 47 percent in 2010, and 1 liter of gasoline costs just over \$1.50 (BITRE, 2012b, Appendix A, Per Cent Tax Table).

## United States

Historically, gasoline prices have been quite low in the United States. Although many early cars were electric, the discovery of plentiful oil helped the internal combustion engine become the standard. Once the cost of the vehicle was paid, car trips were cheaper than streetcar trips for the average family (Jackson, 1985). Gas prices remained low while incomes rose. From 1947 to 1973, gas prices increased from \$0.23 to \$0.39 per gallon in current dollars (Vehicle Technologies Office, 2005).<sup>3</sup> This means that, in real terms, the price of gasoline actually decreased about 15 percent during this period, even as the average annual growth in real personal income per capita was more than 2 percent for the same period (Bureau of Economic Analysis [BEA], undated). The United States also has low fuel taxes by international standards. The national tax was last raised to \$0.184 per gallon (\$0.049 per liter) in 1993, and additional effective state taxes vary from \$0.264 to \$0.69 (\$0.069 to \$0.182 per liter) (American Petroleum Institute [API], 2013).<sup>4</sup> In 2010, only about 18 percent of the pump price of gasoline was tax, and 1 liter cost only \$0.73 (in 2010 U.S. dollars) (BITRE, 2012b, Appendix A, Per Cent Tax Table).

<sup>3</sup> Although inflation was generally low during this time, this is an unusually low rate of increase (44 percent) for a consumer good. During a similar period (1919 to 1970), the price of foodstuffs increased substantially more: flour by 66 percent, coffee by 110 percent, and pork chops by 174 percent (Bureau of Labor Statistics, 1975).

<sup>4</sup> The API calculations add estimates of sales taxes and local taxes paid to the flat per-gallon tax, so these figures represent what the average driver actually pays per gallon.



## Pro Car Policies

This section describes policies, levied at various levels of government, that affect car ownership and driving directly through taxes and fees, vehicle standards, registration, parking management, and other restrictions. Policies affecting fuel, road building, and land use are covered in other sections of this chapter. Of the four OECD countries, the United States has consistently had pro-car policies (or at least no anti-car policies), while the other three have had more variation in their car policies over time.

### Australia

Australia's policies encourage car ownership and driving in some ways; in others, they do not. Parker (2003) suggested that the practice of subsidizing car use as part of a salary package has encouraged the purchase of vehicles that are larger than consumers would have purchased otherwise. Until 2011, the rate of fringe-benefit tax charged to an employee who drove an employer-provided car was based on the ratio of kilometers driven for personal use, which created an incentive to drive additional kilometers. This rule changed in 2011 to a flat tax (Cain, 2011). On the other hand, Australia pioneered the use of graduated driver's licenses, which make younger drivers wait longer and gain more experience behind the wheel than licensing policies that provide a full and unrestricted license immediately. Also, several Australian cities have policies requiring landowners to pay per-space taxes on parking they own; to discourage commuting by car, rates differ between short- and long-term use.

### Germany

In Germany, policies have gone through several shifts from not favoring cars to favoring cars to favoring alternatives. Until the 1920s, cars were subject to luxury taxes, which hampered the growth of the car industry to some extent. In 1926, the tax was dropped, and tax policies began favoring vehicle ownership through incentives for vehicle purchases, as well as for owning used cars (Overy, 1975). After World War II and the partition of Germany, East Germany discouraged individual car ownership, while West Germany invested in both roads and transit. The introduction of tax benefits for home-to-work trips longer than 6 km and low interest rates for auto loans resulted in increased ownership of vehicles. Motorcycles and motor scooters were initially popular, but, eventually, car ownership rose with incomes (Baron, 1995). Since reunification, Germany has generally sought to discourage vehicle ownership. The cost to acquire a driver's license is relatively high (€1,560, more than US\$ 2,000) (Buehler, Kunert, and Pucher, 2009), and many German cities are increasingly restricting the supply of parking and increasing parking costs for private automobiles.

## Japan

Postwar policies favored vehicle ownership as a tool to promote economic growth. In addition, in the early 1960s, manufacturers and banks introduced extended warranties and auto loans, two incentives that probably contributed to greater vehicle purchases (JAMA, undated). However, current policies make vehicle ownership fairly expensive. The various vehicle taxes add approximately 43 percent to the cost of a new car (Takahashi, 2011). Also, all vehicles are required to have an inspection, called “shaken,” three years after they are manufactured and every two years thereafter. Not only is the shaken relatively expensive, but its stringent requirements make it difficult for cars to pass once they are more than six or seven years old. This is thought to lead to higher fleet turnover than in other countries (Flath, 2003).

## United States

The U.S. approach to car ownership and driving could probably best be described as *laissez-faire*. With such large domestic car production, levying import duties on cars would have had a fairly muted impact on vehicle ownership, at least through the 1970s, when higher-mileage imported cars gained substantial market share. The main national policy affecting vehicles was the introduction of mandatory fuel-economy standards, called Corporate Average Fuel Economy (CAFE) standards, which were implemented in the 1970s to reduce gasoline consumption after prices spiked because of the oil shocks. At the time, only cars were subject to CAFE standards, which helped promote sport-utility vehicles (light trucks with substantially lower fuel economy than cars) as personal vehicles. National tax policies allow employers to provide free employee parking as an untaxed benefit, which is thought to contribute to the high drive-alone share of commute trips (Mann, 2005). Vehicle registration and driver licensing are controlled at the state level. Land-use and parking policies, which often favor driving (whether deliberately or inadvertently), are set by local governments. Although the cost of vehicle registration and the requirements for providing parking do vary substantially, no cities or states have adopted major restrictions on vehicle ownership or driving.

## Lack of Alternatives to Driving

This factor considers the availability of alternative transportation modes, with a focus on public transportation and, in particular, rail. (Data on bus systems and nonmotorized modes are less readily available across countries.) This section also cites the Greendex survey (National Geographic and Globescan, 2009) figures on the percentage of residents with access to public transportation. According to these survey findings, Americans are the least likely to have access to transit, while Germans are the most likely.

### Australia

Australia's largest cities are served by rail systems, including the world's largest streetcar network, in Melbourne (Yarra Trams, undated). Fifteen percent of Australians report having no access to transit, while 33 percent have "easily available" access. In addition, a large intercity rail network connects most cities. Its development took place in a more piecemeal fashion than those in other countries, in that much track was laid in the period before federation, when each colony operated independently of the others. For example, the 20,000 km (12,427 miles) of track laid by 1900 used three different rail gauges. Not until 1921 did the new country agree on a standard gauge (Australia Department of Infrastructure and Regional Development, undated).

### Germany

Germany has a large supply of public transport infrastructure, including rail lines dating back to the early 1900s. From World War II to reunification, both East and West Germany maintained their transit systems. In the late 1960s, the West German government instituted a fuel tax, in part to fund larger public transport projects. Between 1967 and 1993, around 55 billion deutschmarks (approximately \$33 billion at the 1992 exchange rate) were invested in public transport, equaling the amount invested in urban road projects (Baron, 1995). To promote transit use, discounts were offered to elderly users, and various parking restrictions were put in place in urban areas starting in the 1960s (Buehler and Nobis, 2010). Overall, transit ticket prices in real terms fell from 1980 to 1993 (Pucher and Kurth, 1995). Further, in the 1970s, cities in West Germany introduced traffic-calming measures to promote nonmotorized transport modes, such as walking and cycling. As of 2009, only 3 percent of Germans reported having no access to transit, while 49 percent said that it was "easily available." The German Unity Transport Projects program upgraded rail in the previous East Germany and improved East-West connectivity. Germany also has a high-speed rail network.

## Japan

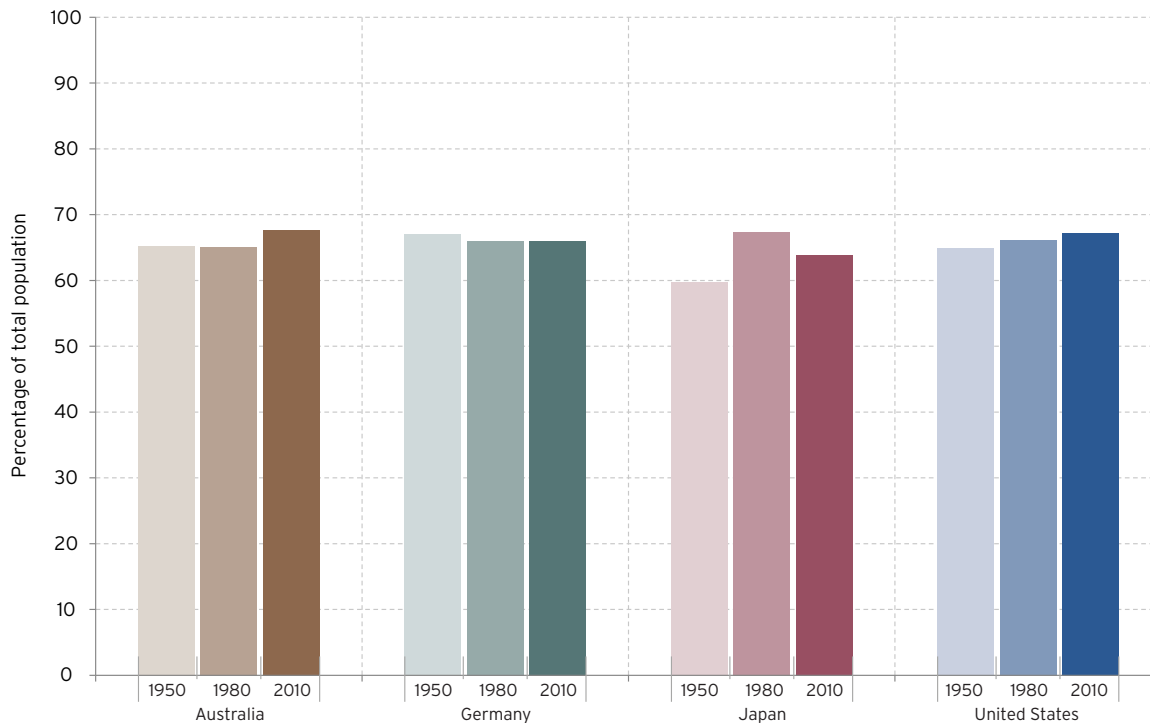
Japan has a long history of investing in both urban and intercity rail. Electric trams spread in the early 1900s, followed by suburban rail in the 1910s and 1920s. The major 1923 earthquake in Tokyo led to reconstruction projects that linked many outlying areas to the city via rail. Even as car ownership expanded enormously in the 1960s and 1970s, rail systems continued to grow; six new subway systems were built from 1950 through the 1980s (Aoki, 1993b). Only 4 percent of Japanese say they have no access to transit, while 54 percent say that it is “easily available.” Japan also built the world’s first high-speed rail line, which opened in 1964. This Tokaido line between Tokyo and Osaka currently carries almost 150 million passengers per year and has never experienced a fatal accident. Japan currently operates 2,200 km of high-speed rail (Amos, Bullock, and Sondhi, 2010). The Shinjuku train station is the world’s busiest, serving 3.5 million passengers per day (“The World’s Busiest Train Stations,” 2012).

## United States

The provision of alternatives to driving in the United States varies not only by city but also within urbanized areas. Essentially all cities, even small ones, operate bus systems, but many of these systems provide very limited services and function as social services provided to elderly, disabled, or low-income patrons. Most large and medium-sized cities have rail systems (including light, heavy, or commuter rail, and, in the largest cities, more than one system), but, in large portions of those urbanized areas, service is infrequent or nonexistent. (Many light rail systems were dismantled in the 1950s, when ridership fell after World War II.) It is indicative of the lopsided nature of transit provision in the United States that one in every three transit trips is taken on the New York City subway (American Public Transportation Association, 2012). Thirty-two percent of Americans report that they have no access to public transportation, and another 15 percent reported that their access was quite limited, while fewer than 20 percent said that transit was “easily available.” One reason for this relative lack of investment in many cities is that, historically, the federal government paid a lower share of the capital costs of transit investments than of roads. Bikeways and sidewalks have varied in quality and quantity (as measured in center-line kilometers) over the years, although, in the past decade, more cities have built them or made them more accessible (Pedestrian and Bicycle Information Center, 2010). Although most major cities are connected via an intercity rail network, only one corridor operates at high speed (Washington to Boston).

## Active Population

Active population refers to the share of the population in a life stage characterized by high mobility rates—for example, those of working age, those likely to have children at home, and those who are more likely than others to travel for shopping or leisure purposes. We used three sets of figures to compare active population across countries: (1) the share of the population in the age range 15 to 64, beginning in 1950 (OECD, undated; see Figure 5.3); (2) the percentage of that age cohort who actively participate in the labor force, beginning in 1980 (World Bank, 2013); and (3) the overall labor-force participation of women, beginning in 1980 (World Bank, 2013). Although the changes in active population that would have most affected the period of the greatest growth in mobility took place prior to 1980, we have not found comparable data in a longer time series. The countries do not differ sharply on this factor; the proportion of people in the 15–64 age cohort has remained steadily between 65 and 68 percent in all countries but Japan, where it has declined. Overall and women’s labor-force participation has risen in all countries from 1980 to 2009, again except in Japan.



**Figure 5.3. Working-Age (15–64) Population as a Percentage of Total Population**

SOURCE: OECD, undated.

## Australia

Australia's 15-64 population increased from 65 percent in 1950 to 68 percent in 2010. Overall labor-force participation increased from 62 to 65 percent from 1980 to 2010. A key contributor to this trend was strongly increasing female workforce participation, which rose from 45 percent in 1980 to 59 percent in 2010, the largest increase in the four countries during this period. In a study of commuting behavior between 1967 and 2001, Parker (2003) found that the number of female drivers commuting to work nearly tripled during this period, from 0.75 million to more than 2 million, whereas the number of male drivers increased by only one-fifth.

## Germany

The trend is similar in Germany. From 1950 to 2010, the percentage of population between 15 and 64 declined slightly from 67 to 66 percent. Total labor-force participation rose from 55 percent in 1980 to 60 percent in 2009 (the largest percentage-point change among the four countries). Female participation in the labor force was a contributing factor here; the proportion of women working rose from 41 percent in 1980 to 53 percent in 2010.

## Japan

Of the four OECD countries, Japan has seen the greatest change in the share of population between 15 and 64 years of age. In 1950, it was 60 percent; it rose to 67 percent in 1980 before falling to 64 percent in 2010. This is driven largely by demographic change, with an aging population characterized by both high life expectancy and low fertility rates. (Life expectancy at age 65 and age 80 increased more in Japan in the mid-20th century than in any of the other countries [G. Anderson and Hussey, 2000].) As of 2008, Japan's population began shrinking (Japan Statistics Bureau, 2012b, Table 2.3). Labor-force participation is relatively low, decreasing from 63 to 60 percent from 1980 to 2010. Women's labor-force participation remained essentially stable, increasing from 48 to 50 percent during this period.

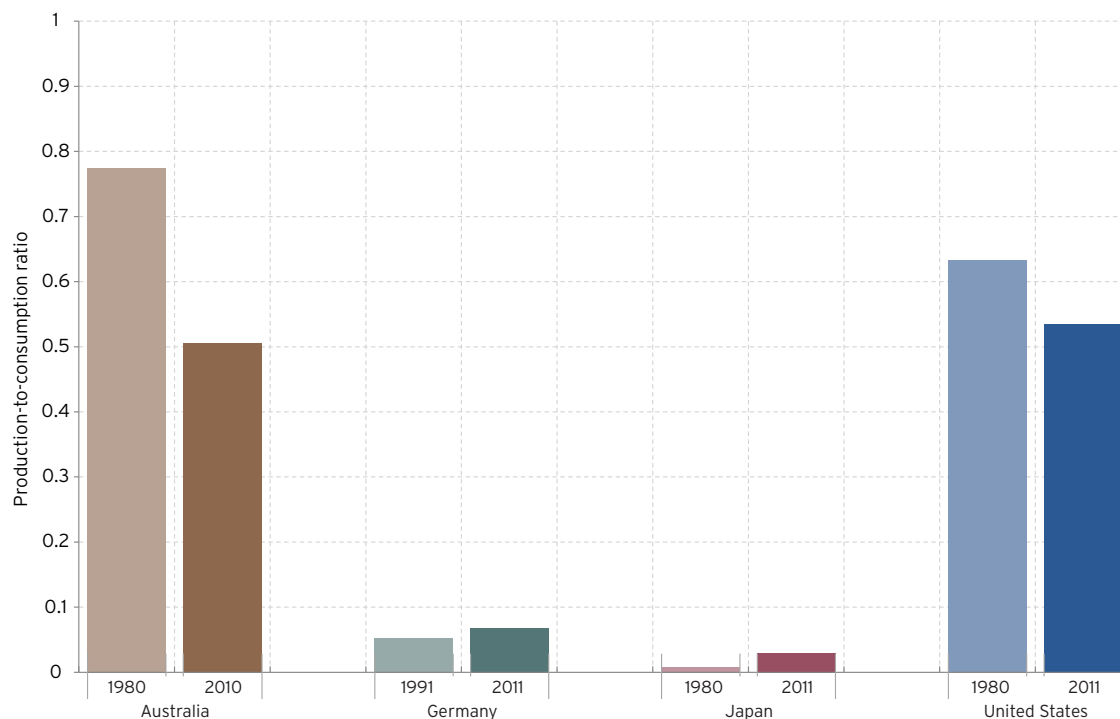
## United States

The share of population between 15 and 64 years of age has risen only slightly from 1950 to 2010, from 65 to 67 percent, and their labor-force participation rate increase was similarly small, from 64 to 65 percent from 1980 to 2010. The percentage of women in the labor force rose from 51 to 58 percent during this same 30-year period; however, the previous increase was much more pronounced, from 34 percent in 1950 to 45 percent in 1970 (Fullerton, 1999, Table 1). The so-called baby boomers, people born between 1946 and 1964, also constituted a large cohort that was still engaged in the labor force from 1980 to 2010. The oldest members of this cohort were just reaching the traditional retirement age of 65 in 2011.



## Existence of Domestic Oil

The presence of oil is considered an indirect factor, in that the government of a country with plentiful oil may encourage consumption to help a major industry (as in the United States). It may also encourage a country with little or no domestic production to promote energy-efficient transportation modes (as in Germany or Japan). For the domestic oil factor, we look at both production and consumption to determine a country's relative oil independence. In this section, we use 2011 oil consumption and total oil production statistics (EIA, undated); see Figure 5.4 for one cross-country comparison.



**Figure 5.4. Domestic Oil Production Divided by Domestic Oil Consumption**

SOURCE: EIA, undated.

NOTE: Data for Germany begin in 1991, the first full year of reunification.

## Australia

Australia produces only modest amounts of oil, about 525,000 barrels per day. However, given its fairly small population of roughly 22 million, it is not a major consumer either. Its oil consumption is just over 1 million barrels per day, the lowest of the four countries. However, consumption has nearly doubled since 1980, when it was about 600,000 barrels per day.

## Germany

Germany has never been a major oil-producing country. As of 2011, it produced about 165,000 barrels per day, a fraction of its consumption of 2.4 million barrels per day. Germany is the largest energy consumer in Europe, except Russia, and it has significant crude-refining capacity. For the past 20 years, production has increased modestly, while consumption has declined.

## Japan

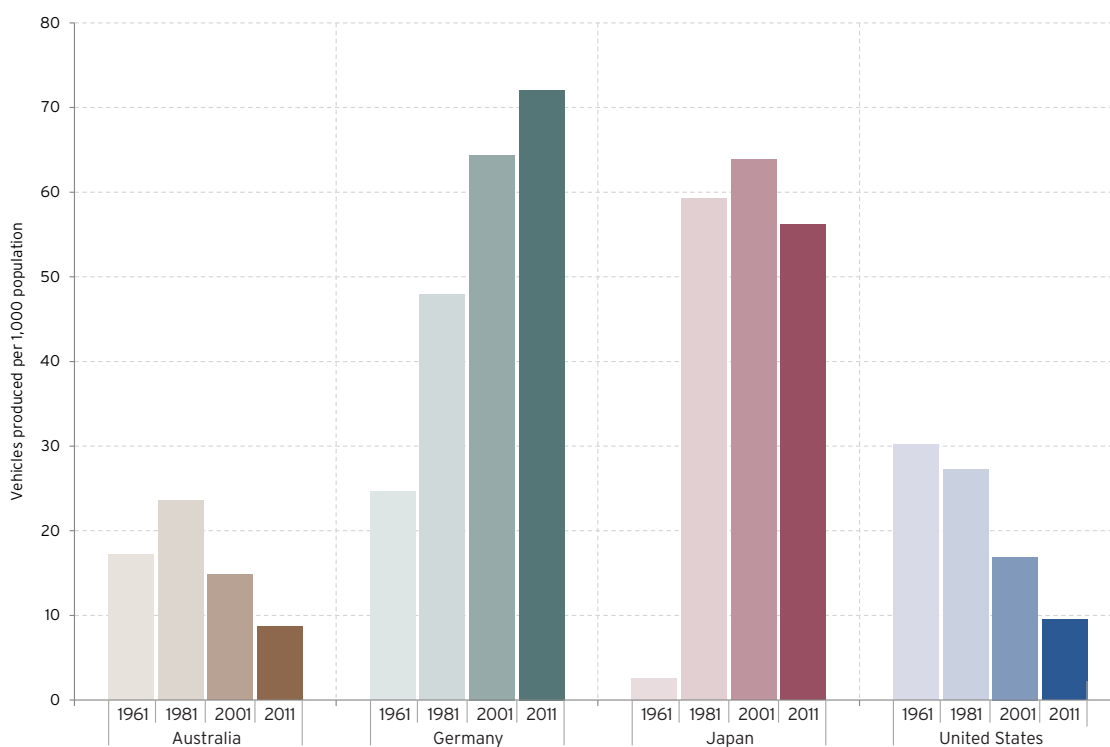
Of the four countries, Japan is the most heavily dependent on imported oil. It has never produced any significant amount of oil, and, at the time of the 1973 oil shock, Japan imported 80 percent of its oil from the Middle East (JAMA, undated). Japan produces only 136,000 barrels of oil per day, 3 percent of the 4.5 million barrels it consumes. Consumption rose in the 1990s but is lower now than in 1980.

## United States

The United States is currently the world's third-largest oil producer, second only to Saudi Arabia and Russia, producing roughly 10.1 million barrels per day. However, it is also the world's largest consumer, using an estimated 18.9 million barrels per day. As a result, it is a net oil importer, importing roughly half of its oil. Two major sources of oil were discovered in the United States in the early days of motorization—Southern California in the 1890s and Texas in the 1900s—and the country has been a major oil producer for a century. Oil production had been falling for the past several decades but has increased sharply since 2006 because of technological advances that allow drilling in areas where oil had previously been too expensive to extract.

## Strength of the Domestic Car Industry

The presence of a domestic car industry is considered an indirect factor, affecting driving and vehicle ownership by influencing other factors, such as pro-car policies. Early car experiments and technologies date to the late 1800s, and mass-market production first began in the early 1900s. However, there does not seem to be a solid, direct link; the United States, Germany, and Japan all have strong domestic car industries (see Figure 5.5), but Australians own more cars than either Germans or Japanese. The data in Figure 5.5 refer to all vehicles manufactured (cars and trucks).



**Figure 5.5. Total Vehicles Produced per 1,000 Population**

SOURCES: For vehicle production, BTS, undated, Table 1-23 (updated October 2012). For population, U.S. Census Bureau, 2013.

## Australia

Despite having a domestic car industry, Australia has never been a major auto manufacturer. Its relatively modest vehicle production rose from 231,000 in 1961 to about 470,000 in 1971, and has gradually declined since (BTS, undated, Table 1-23).

## Germany

Germany was the center of automobile innovation in the late 1800s and has retained a strong industry. In the 1930s, the industry received several boosts in the form of special tax incentives for car purchases and tax relief to the auto industry on sales of new vehicles (Overy, 1975, p. 474). Car production boomed in the post-World War II years, rising from about 300,000 in 1950 (when it produced fewer cars than France or Italy) to more than 2 million in 1960 (Pratten and Silberston, 1967). Currently, Germany produces more than 6 million vehicles per year, making it the world's fourth-largest manufacturer (BTS, undated, Table 1-23). The auto industry is the country's largest employer, with about 600 companies and roughly 700,000 employees or 2 percent of the total labor force (Verband der Automobilindustrie, undated; Eurostat, undated).

## Japan

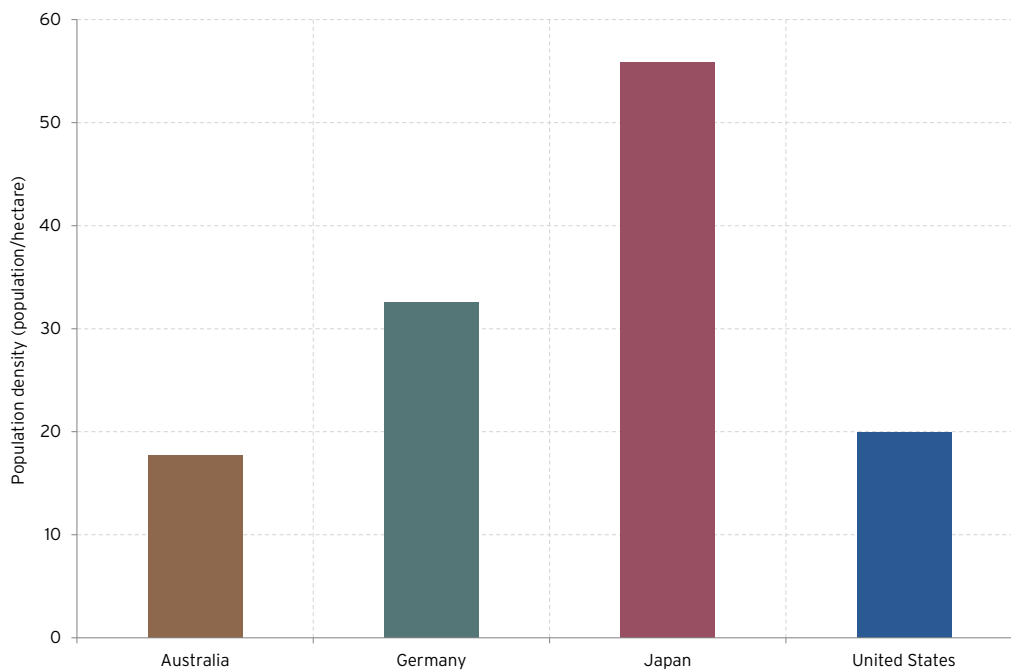
Despite its current prominence, Japan came relatively late to auto manufacturing. There was very little domestic vehicle industry in the prewar years, and Japan's industrial base was devastated in World War II. In the 1950s, however, the national government targeted the car industry as one of several sectors that would help create a modern, developed economy. Auto manufacturers were eligible for tax advantages and low-cost government loans, and they reacted eagerly to the government's People's Car Plan of 1955, which called for development of a small, reliable, and affordable vehicle. By 1966, Japan was the world's second-largest producer of cars, and, by 1972, the automotive industry represented 10 percent of Japan's total economic output (JAMA, undated). Japan began to make inroads into the lucrative U.S. market in the 1970s, after the oil shocks made fuel-efficient cars more attractive to American buyers. Although total numbers have fallen from their peak in 1990, when the Japanese economy entered a period marked by economic stagnation, Japan still produces more than 8 million cars per year and is the world's third-largest producer (BTS, undated, Table 1-23).

## United States

The United States was not a leader in automobile manufacturing in the very earliest days, but it quickly caught up. In the early 1900s, Henry Ford developed an assembly line that allowed for specialized labor to produce automobiles quickly and cheaply, which led not only to a revolution in manufacturing but also to the United States' dominance of global automobile production. In 1950, the United States produced more than 8 million vehicles, while other major vehicle-producing countries produced fewer than 1 million each (Pratten and Silberston, 1967). However, the auto industry was dealt a major blow in the oil shocks of the 1970s, after which a combination of government efficiency regulations and changing consumer tastes for smaller vehicles led to cars from other countries entering the U.S. market in large numbers. Although total U.S. auto production continued growing through 2000, it has been gradually declining since, along with the industry's number of employees and political influence. The United States still produces more than 8 million cars annually but lost its status as the world's largest vehicle manufacturer to China in 2008 (BTS, undated, Table 1-23).

## Spatial Dispersion

This factor includes both the degree of urbanization and densities within urban areas. Data on the density of urban areas in 2000 are taken from Angel et al.'s Atlas of Urban Expansion (2010, Table 3); see Figure 5.6. Australia has the lowest total density, while Japan has the highest.



**Figure 5.6. Population Density in Urban Areas, 2000**

SOURCE: Angel et al., 2010, Table 3.

## Australia

Australia has a high degree of urbanization but at low densities: 18 people per hectare (7.3 people per acre). Like the United States, its early urbanization was characterized by fairly tight-knit hub-and-spoke configurations centered on light rail systems. After World War II, the process of low-density suburbanization accelerated. In a case study of Perth, for example, the War Service Homes Scheme financed land ownership and detached dwellings for returning servicemen. Planning also played a role, with strategic plans emphasizing low development densities, segregated land uses, and a lack of rigid urban growth boundaries. State and federal funding facilitated the construction of urban freeway systems that enabled commuting between decentralized residential areas and places of employment (Falconer, Giles-Corti, and Lyons, 2007).

## Germany

Germany is fairly urbanized, with about 74 percent of the population living in urban areas (CIA, undated). The average density of urbanized areas is 32 people per hectare (13.1 people per acre). The last major wave of changes in urbanization came at the end of World War II, when millions of refugees flowed into West Germany. This increased population densities in the urban areas, prompting local authorities to introduce a variety of tax benefits to promote housing for small households. As a result, newer urban areas were developed with lower population densities (Baron, 1995).

## Japan

Of the four countries, Japan has by far the highest urban population density, 56 people per hectare (22.7 people per acre). Tokyo, the capital, is the world's largest urban area, with 34.5 million inhabitants (Brinkhoff, 2013). Much of Japan's urban development took place around rail systems, beginning with trams in the early 1900s, suburban rail in the 1910s and 1920s, and subways in the postwar years. Extensive intercity rail networks have probably helped urban centralization.

## United States

Although roughly 80 percent of Americans live in urbanized areas, only 30 percent live in cities (as defined by the U.S. Census Bureau). The other 50 percent live in suburban areas, where housing densities tend to be low (Hobbs and Stoops, 2002). The average density of all urbanized areas is 20 people per hectare (about 8.1 people per acre). The United States has been suburbanizing since the 1900s through 1920s, when developers extended streetcar lines out to suburban areas to create transportation for new housing developments. Suburbanization was also abetted in the 1950s and 1960s with the creation of a national interstate system that brought not only residents but also employers and retail to suburban locations. In the 1940s, about 80 percent of housing was built in cities and suburbs. By the 1960s, more than half of new housing units were in suburbs (Williams, 2004).



## Favorability of Car Culture

Car culture is our label for the set of beliefs, expectations, and attitudes about driving and car ownership and their manifestations in a country's culture. As such, this factor is the most subjective. One source of comparable data across 17 countries is a survey about environmental attitudes, which may be linked to attitudes about mobility (National Geographic and GlobeScan, 2012). One product of this survey is the Greendex score, which reflects survey responses about consumer behavior. In this section, we cite figures from the transportation Greendex, which develops a score based on questions about driving, size of vehicles, ownership, distance traveled, and use of nonautomobile modes. The index is scored from 0 to 100; the higher the score, the more environmentally friendly the attitudes of a country's people. All survey data cited in this section are from this source.

In addition, for the workshop, the country experts conducted a separate exercise to develop a car-culture score for each country. This incorporated expert opinion along seven dimensions: the importance of cars (1) to feel independent and individual, (2) for personal space and privacy, (3) to express certain attitudes and beliefs, (4) as a social norm, (5) as a hobby, (6) as a personal living space, and (7) in popular culture. Country experts were asked to assign scores ranging from -2 (the least car-oriented) to 2 (the most) to each of the seven dimensions for each country and to assess whether the score increased over the motorization period or not. Subsequently, an average score for each country was computed, discussed, and amended among the expert group.

## Australia

As in the United States, early automobile adoption was common, and for similar reasons. Prior to 1920, cars typically cost several times the annual minimum adult male wage, but, by 1925, a new car could be purchased for less than one year's pay (Knott, 2000). The motor vehicle was seen as symbolizing progress and technology, car ownership offered a sense of mobility and freedom, and driving was seen as thrilling and exciting. The ability of speed to conquer distance was another important factor, particularly for those living in remote rural areas, where distances could be vast. Australia's Greendex transportation score is a fairly low 58.2, and only 45 percent of survey respondents were concerned about climate change. On the car-culture scoring, Australia was second-highest, with a 1.2. Experts rated Australia as the highest of the four countries on the car as personal living space and for privacy.

## Germany

Among European countries, Germany has been strongly car-minded. Some of this quality may stem from Germany's long-established tradition of manufacturing high-performance cars and its autobahn system. However, the younger generation today seems to be increasingly multimodal (Kuhnimhof, Buehler, and Dargay, 2011). In the Greendex survey, the German transportation score was 61.9, and 51 percent were concerned about climate change. Germany rated a 0.2 on the car-culture score. It was moderately high in all dimensions except as a social norm, on which Germany received the only negative score of the four countries.

## Japan

As noted elsewhere in this report, Japan was relatively late to motorization. As late as 1968, vehicle ownership was less than 100 per 1,000 people. However, cars became popular consumer goods in the 1960s, when they were considered one of the "three Cs"—cars, air conditioners, and color televisions, the consumer goods that most households wanted (JAMA, undated). Japan had the highest Greendex transportation score of the four countries (65.9), and 65 percent were concerned about climate change. Japan's car-culture score was -0.1. It was the only country of the four to receive a negative score on personal living space and as a hobby, but it rated very high as a personal expression.

## United States

The United States has a reputation as a country where cars and driving are very important to personal identity. In the Greendex survey, Americans ranked very low on concerns about climate change, with only 45 percent expressing concern. Americans' Greendex transportation score was 54.9, the lowest of all 17 countries surveyed. Although licensing and VKT have both declined slightly in the past decade, it is not clear what has caused these changes or whether they represent the start of a new trend or a temporary aberration. The car-culture score provided by the expert was the highest of the four countries, at 1.4, and all dimensions of car culture were perceived to be relatively important.



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# Chapter Six

## Future Mobility Paths of Brazil, Russia, India, and China

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In this chapter, we use the findings from the analysis of the factors in the OECD country case studies regarding factors that influence mobility to estimate future travel in the BRIC countries. As noted in Chapter Three, we held an expert workshop to conduct much of this analysis. The two-day workshop took place in Berlin in April 2013. In this chapter, we discuss the three main results of the workshop: factor scores, factor weights, and automobility scores. We then explain how we think these will affect future patterns of mobility, as well as long-term travel saturation rates, as measured in VKT per capita.

## Workshop Results

At the workshop, each of the eight countries was represented by national experts who participate in the Institute for Mobility Research's (ifmo's) Global Mobility Monitor Network (GMMN).<sup>1</sup> We invited one expert for each OECD country and teams of two or three experts for each BRIC country (expert names and affiliations are provided in Appendix B). The difference in team size for the OECD and BRIC countries reflects the challenges in assessing the factors for the BRIC countries. For the OECD countries, the availability of information was generally better, partly because we needed only historical and current information. For the BRIC countries, on the other hand, future estimates for the factors were necessary—at least to describe the situation at a level of GDP per capita of \$20,000 and, in some cases, even for \$5,000.

### Factor Scores

We developed scores for each of the nine influencing factors to (1) quantify all the factors in a comparable manner and (2) capture changes in the factors over time. The scores indicate the situation of the factor in a country at a point in time. As noted in Chapter Two, scores were provided on a scale ranging from -2 to 2. A 2 rating on a factor meant that the situation encouraged automobility in the country, while a -2 discouraged it. A rating of 0 was neutral. For example, for the domestic oil factor, a 2 means that a country has a large supply of its own oil and is not reliant on imports. A -2 means that a country has very limited domestic oil and is therefore highly reliant on imports. The factor scores thus describe the range of conditions for the countries.

To arrive at these scores, prior to the workshop, we presented the experts with a fact sheet that summarized the factor trends in each OECD country, based in large part on the information in Chapter Four. Some factors contained a clear quantitative component (such as domestic car industry and fuel price); for these, we prepared time-series data or selected statistics that covered the respective study periods as comprehensively as possible. Others were largely or entirely qualitative (such as car culture). In these cases, either we presented selected statistics only for specific years to provide a baseline for comparisons across countries or we resorted to purely descriptive information. Figure 6.1 provides an example of a fact sheet (all fact sheets are provided in Appendix C).

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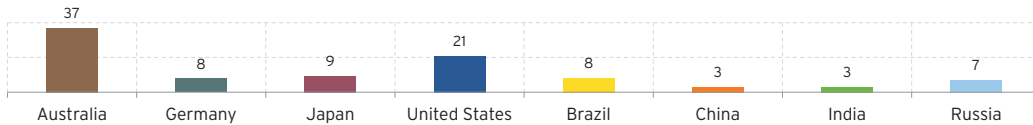
<sup>1</sup> The GMMN was initiated by ifmo in 2012 to assess the recent history, status quo, and future prospects of mobility in selected countries around the globe. The GMMN is made up of a global network of renowned transportation experts and aims to provide information to international stakeholders in the field of mobility products and services. These study countries are Germany, the United States, and the BRIC countries; each country is represented by a group of up to three experts. The program includes expert workshops and other research activities. For the workshop, the GMMN was supplemented with experts from Japan and Australia.

## Good Car Infrastructure

This factor is made up of all infrastructure for automobility, including the quality and quantity (in center-line kilometers) of roads and parking supply.

### Fact Sheet and Expert Observations

Total road network (center-line meters per population), 2008-2011



#### OECD countries

##### Australia:

- Road infrastructure is extensive but includes a large share of unpaved roads.

##### Germany:

- The first autobahn was finished in 1932, part of extensive investment in roads in the 1930s to 1950s.
- There was a second wave of road investment in 1960s West Germany.
- There is limited parking supply.

##### Japan:

- There were few paved roads even in the 1950s but massive investments in road building in 1960s and 1970s.
- There is very limited parking infrastructure.

##### United States:

- The good-roads movement started in 1880s.
- There were major roadway investments in the 1920s, and interstates were built in the 1950s and 1960s.
- There is substantial parking supply.

#### BRIC countries

##### Brazil:

- There is good overall road penetration, but quality and quantity in urban areas are deficient.
- In recent years, congestion levels have increased massively.

##### China:

- The road network has extended rapidly.
- The extension has taken place mostly in small cities, where space is available.

##### India:

- There are insufficient parking arrangements in Indian cities, but the situation is expected to improve because of construction.
- There is also notorious chaos resulting from congestion, but facilities are improving over time.

##### Russia:

- Recently (and in the midterm future), there has been substantial investment in road infrastructure.

Figure 6.1. Sample Fact-Sheet Slide for Car Infrastructure

SOURCE: For center-line meters, CIA, undated. For population, World Bank, 2013.

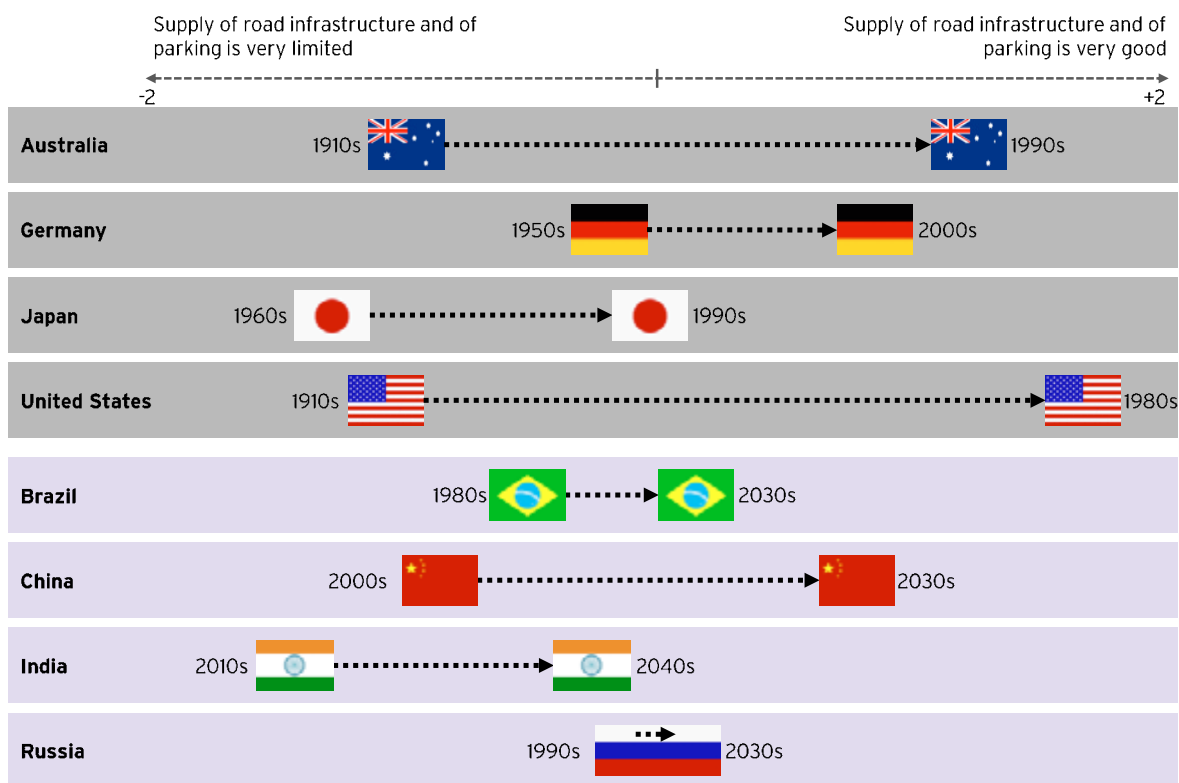
NOTE: The shaded area shows the expert opinions expressed at the workshop. The rest of the figure consists of information provided to the experts.



At the workshop, we asked the experts for their opinions about the factors presented for the OECD countries—whether the information in the fact sheet seemed to be relevant to the factor and their thoughts on additional information to consider. In addition, we asked for expert opinion about the future situation in the BRIC countries. For example, what does the current state of the domestic car industry suggest about how prominent the industry might be when the country enters the motorization period at \$5,000 per capita? This information was summarized for side-by-side comparison between countries.

We developed a system for assigning factor scores that workshop participants nicknamed the “flag game.” Each factor has one chart with a row for each country (see Figure 6.2). Each row contains two of a country’s flags positioned along a horizontal axis. The left-most position of this axis represents a score of -2, a situation in which automobility is expected to be low. The right-most position of the axis represents a score of 2, a situation very conducive to automobility. The position of one flag represents the factor situation at the beginning of the motorization period (when GDP was at \$5,000); the position of the other flag shows the factor situation at the end of the period (when GDP was at \$20,000). The direction and the length of the arrows between the flags represent the changes that have taken place during this period. The group discussed the relative positions of each flag, and these were translated into factor scores that quantify expert judgment about the situation for each factor for each country at each of the two points in time. For example, in Figure 6.2, the United States has fairly low-quality car infrastructure in the 1910s but very well-developed infrastructure by the 1980s.

The strength of the flag game was that experts could compare the situation for the different factors—at two different crucial points in time—across countries. However, the factor scores are not absolute scores. Instead, they should be seen as relative scores that describe the historical, current, or future situation in the countries in comparison with each other and over time. A screenshot of one flag-game page is provided in Figure 6.2. The entire set of fact sheets and flag-game results is presented in Appendix C.



**Figure 6.2. Sample Flag-Game Slide for Car Infrastructure**

SOURCE: Created by ifmo for expert workshop.

After the workshop, we summarized the factor scores and flag-game results and sent them to each expert for validation. The readjustment of the factor scores in this validation process was minimal. According to this result, our expert participation seems to have provided sufficient iteration to arrive at agreed-upon factor scores. Ultimately, the positions of the flags were translated into 18 numeric scores per country (two time periods multiplied by nine factors), which describe each factor at two points in time on a scale from -2 to 2.

## Factor Weights

We assume that the factors have differing levels of influence on automobility. To account for this, we introduced factor weights on a three-point scale (on which 3 represents the strongest influence on automobility and 1 the lowest) to capture the variance of influence across factors. We developed the factor weights based on expert judgment at the workshop through a moderated discussion, as well as follow-up validation via email. The final set of factor weights is an arithmetic mean of the expert judgments after validation, rounded to the nearest integer. At that point, the experts' judgment on the weights had converged such that no individual expert judgment differed from the weight that was finally assigned to the factor by more than 1.

We also considered the possibility that the impact of factor conditions on automobility differs in strength over time. To investigate this, we introduced additional weights for the two points in time. However, these time-based weights were discarded because the experts did not deem them necessary.

Among the nine factors, the two with the most significant influence on automobility were car infrastructure and spatial dispersion. Both of these suggest that the physical environment in which people live plays a key role in shaping their transportation choices, a conclusion that is consistent with other literature on travel demand. The least significant factors were active population and domestic oil. The combination of factor scores and weights is shown in Figure 6.3.

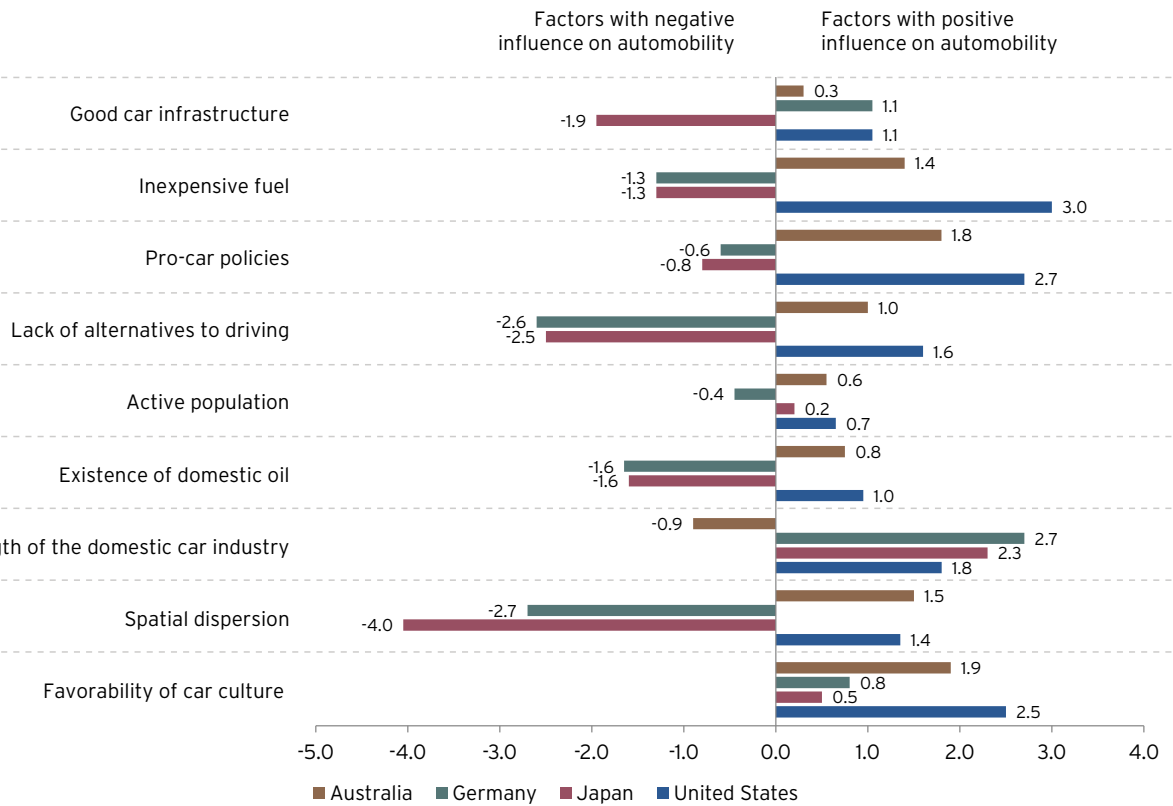


Figure 6.3. Automobility Dimensions for OECD Study Countries

## Automobility Scores

Finally, we developed a single automobility score per country to summarize the influence of the factor conditions during the motorization period. The automobility score was derived by multiplying each factor score by the appropriate factor weight, then dividing that product by the sum of factor weights to keep the scale consistent with the factor scores. (That is, the highest possible score for a totally auto-oriented country is 2, and the lowest is -2.) The scores do not reflect specific changes in the orientation over time but rather an overall orientation during the entire motorization period. The scores achieved by our eight countries ranged from a high of 0.87 for the United States to -0.51 for Japan.

The final factor scores, factor weights, and automobility scores are shown in Table 6.1.

Table 6.1. Factor Scores, Factor Weights, and Automobility Scores for Eight Countries

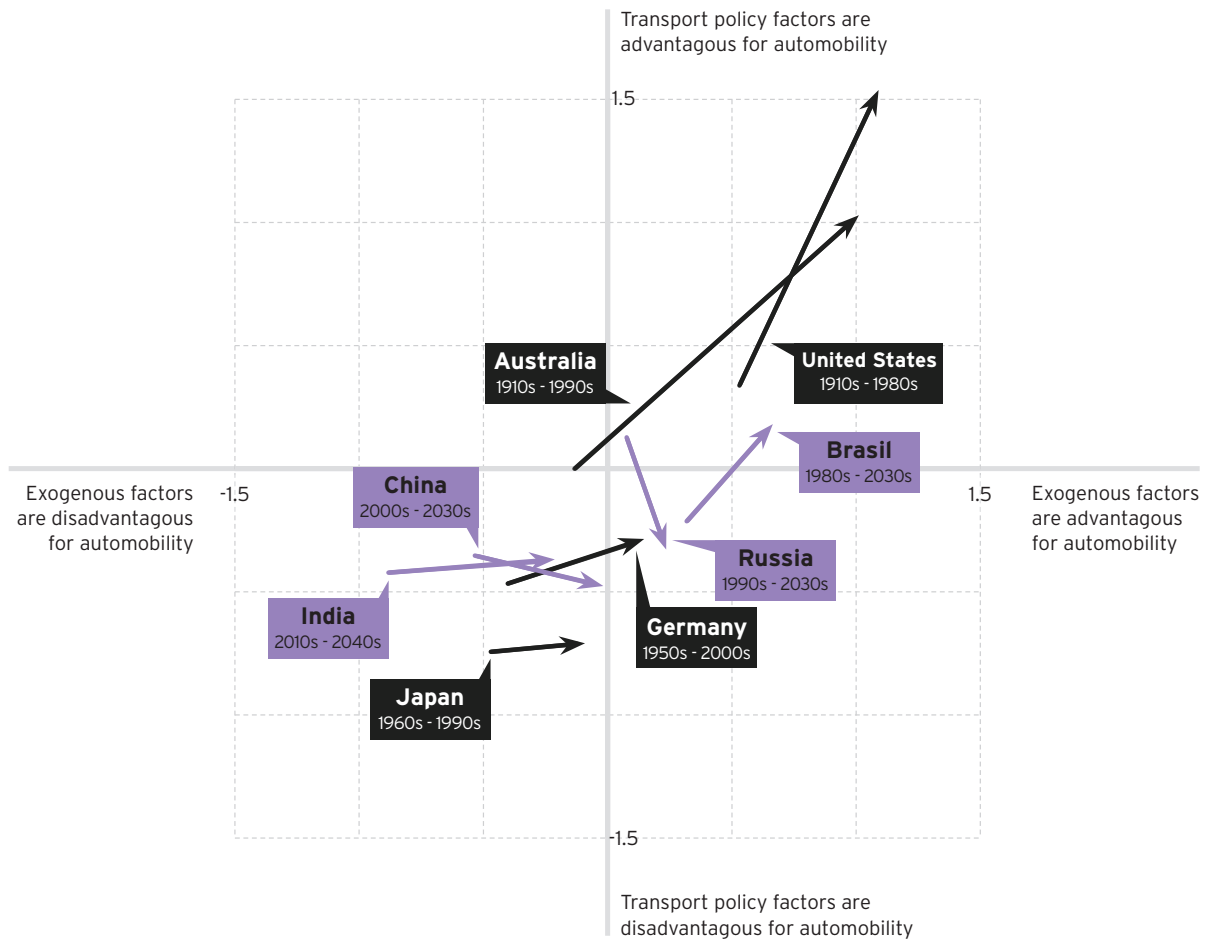
Country			Good Car Infrastructure (3)	Inexpensive Fuel (2)	Pro-Car Policies (2)	Lack of Alternatives to Driving (2)	Active Population (1)	Existence of Domestic Oil (1)	Strength of the Domestic Car Industry (2)	Spatial Dispersion (3)	Favorability of Car Culture (2)	Automobility Score
<b>Factor scores for the OECD countries</b>												
Australia	1910s	-1.2	0.5	1.2	0.1	0.1	1.3	-0.8	-0.8	0.7	<b>0.46</b>	
	1990s	1.4	0.9	0.6	0.9	1.0	0.2	-0.1	1.8	1.2		
Germany	1950s	-0.2	-1.0	0.1	-0.9	-0.9	-1.8	0.9	-1.3	0.6	<b>-0.26</b>	
	2000s	0.9	-0.3	-0.7	-1.7	0.0	-1.5	1.8	-0.5	0.2		
Japan	1960s	-1.3	-1.1	0.5	-0.8	0.4	-1.8	0.7	-1.8	0.6	<b>-0.51</b>	
	1990s	0.0	-0.2	-1.3	-1.7	0.0	-1.4	1.6	-0.9	-0.1		
United States	1910s	-1.1	1.3	1.8	0.1	0.4	1.8	1.4	-0.8	1.1	<b>0.87</b>	
	1980s	1.8	1.7	0.9	1.5	0.9	0.1	0.4	1.7	1.4		
<b>Factor scores for the BRIC countries</b>												
Brazil	1980s	-0.5	-1.0	0.8	0.0	1.1	1.0	0.8	-0.2	-0.1	<b>0.23</b>	
	2030s	0.2	-0.2	1.1	-0.5	1.5	1.4	1.4	0.3	-0.4		
Russia	1990s	-0.1	0.3	1.2	-0.8	0.6	1.8	-0.8	0.1	-0.2	<b>0.03</b>	
	2030s	0.2	-0.2	-0.2	-1.2	0.4	1.6	-0.2	-0.2	0.5		
India	2010s	-1.4	-1.0	0.2	1.0	-0.3	-0.6	-0.8	-1.4	-0.6	<b>-0.49</b>	
	2040s	-0.2	-0.2	-0.6	-0.6	0.8	-0.9	0.3	-1.0	0.0		
China	2000s	-0.8	-1.0	0.3	0.3	1.2	-0.2	0.3	-1.7	-0.6	<b>-0.35</b>	
	2030s	0.4	-0.2	-1.2	-1.3	1.5	-0.6	0.9	-1.1	0.0		

SOURCES: For Decade definitions for OECD countries, Bolt and van Zanden, 2013. For decade definitions for BRIC, see footnote in "Estimating Impacts of Factors on Mobility" in Chapter Three. Factor scores, factor weights, and automobility scores are based on workshop results.

NOTE: Factor scores describe the situation of each factor on a scale from -2 (not conducive to automobility) to 2 (very conducive to automobility) for two points in time: (1) the beginning of the motorization period (\$5,000 GDP per capita) and (2) the end of the motorization period (\$20,000 GDP per capita). Factor weights describe how strongly each factor affects automobility (1 = low impact, 2 = medium, 3 = high).

## Factor Changes over Time

We used the factor scores to analyze how the factors have changed over time. For this analysis, we developed a weighted average of the exogenous and transportation policy factors separately, based on the factor weights. We then plotted them on a graph to show the direction for each country over the motorization period. Figure 6.4 shows the results. For each country, the start and end positions of the arrow shows the weighted factor scores at the start and end of that country’s motorization period. Together, they suggest some key similarities and differences between the OECD and BRIC countries.



**Figure 6.4. Trends in Exogenous and Transportation Policy Factors During the Motorization Period for Eight Study Countries**

SOURCE: ifmo analysis of factor scores



The arrows show that all four OECD countries saw their exogenous factors increasingly encourage automobility while they were in their motorization periods. In particular, conditions in Australia and the United States swung quite dramatically in this direction; in Japan, conditions became more favorable but from a lower starting point. The United States and Japan differ most in the prevalence of sprawl, the availability of domestic oil, and demographic changes. Although the domestic car industry is important in both countries, its relevance has increased in Japan but decreased in the United States.

Japan and the United States were also the most different in terms of transportation policy factors. During its motorization period, the United States saw a large increase in car infrastructure and inexpensive fuel, both of which encourage automobility. The combination of tough regulation, good alternatives to driving, and historically limited car infrastructure makes Japan the country that most discourages automobility. During their motorization periods, Japan and Germany introduced policies that discouraged automobility, while Australia and the United States adopted car-friendlier policies.

Among the BRIC countries, exogenous factors are all moving toward greater automobility, albeit starting from different points on the spectrum. Russia and Brazil have relatively favorable exogenous conditions for automobility: Both have domestic oil, and Brazil has a growing car industry and increasing active population. China and India, on the other hand, lack domestic oil and have much denser cities, so exogenous conditions for automobility are not as advantageous. But all eight study countries move toward conditions that are more amenable to automobility over time. In this respect, the BRIC countries are not too different from the OECD countries; the differences are in the sizes of the increases and the starting points. A key similarity is that, as incomes rise, spatial dispersion—a factor that plays an important role in motorization—tends to increase. Also, the increasing importance of the car industry and rising shares of the population that are active in many countries influence this trend substantially.

The trends for the transportation policy factors are more heterogeneous than for the exogenous factors. In Germany and Japan, the increasing affordability of fuel and the extension of the car infrastructure were kept in check by tougher regulation and expansion of non-car alternatives. This was not the case in Australia and the United States, where policies contributed to increasingly favorable conditions for automobility.

Among the BRIC countries, Brazil exhibits the most favorable policy conditions for automobility and continues to develop in that direction. China and India are closer to the German and Japanese path, in which transportation policies that discourage automobility are not expected to change much over time. In Russia, policy conditions are anticipated to get stricter, mostly because the favorable tax treatment for cars and fuel are not expected to continue into the long-term future.

Figure 6.4 also shows that the countries are generally positioned along the diagonal from the lower left to the upper right, which is also the general direction of movement over the study period. This suggests that the two types of factors are correlated, or that transportation policy seems to move in the same direction as exogenous forces. This pattern is more pronounced for the OECD countries; perhaps the less pronounced pattern for the BRIC countries reflects the experts' opinion that their motorization periods will be less influenced by these factors.

## Estimates of Future Personal Vehicle Travel Saturation in Brazil, Russia, India, and China

The forecasted future paths for automobility in the BRIC countries raise the question of how this translates into personal vehicle travel. To address this question, we first returned to the OECD countries to develop a model of long-term travel saturation. According to historical trends in VKT and GDP per capita, it appears that VKT (like vehicle ownership) follows a typical S-curve—that is, VKT grows slowly at the lowest income levels, then grows more rapidly as incomes increase, and finally slows down as saturation is approached.

Although many different functional forms can describe an S-curve, we used a Gompertz function to model VKT. This is similar to the approach used by Dargay, Gately, and Sommer (2007) to model car ownership. Dargay and Gately (1999) argue that the Gompertz formulation is somewhat more flexible than the logistic model, particularly in allowing different curvatures at low and high income levels. We assume that growth in personal vehicle travel is a function of GDP, an assumption that is consistent with vehicle ownership models of this sort (see Dargay and Gately, 1999, and Dargay, Gately, and Sommer, 2007).

We estimated models with three terms ( $\alpha$ ,  $\beta$ , and  $\gamma$ ) describing the S-shaped curve for each OECD country. The estimated country-specific growth terms  $\beta$  describe the speed of car travel evolution:

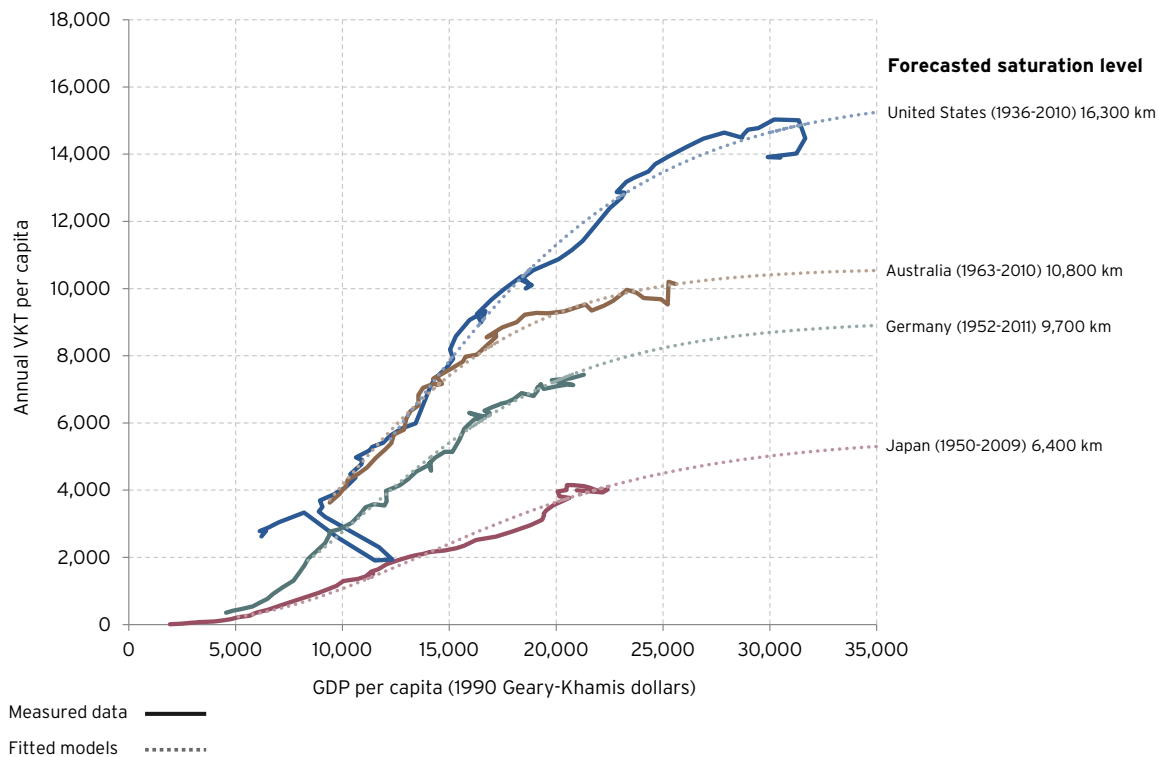
$$\beta_{\text{Australia}} = -0.178$$

$$\beta_{\text{Germany}} = -0.148$$

$$\beta_{\text{Japan}} = -0.114$$

$$\beta_{\text{United States}} = -0.134$$

$\alpha$  defines the curvature at very low levels of GDP and is generic across countries ( $\alpha = -5.495$ ). The resulting country-specific saturation levels  $\gamma$  are shown at the right of Figure 6.5. Further details of the models are presented in Appendix D.



**Figure 6.5. Observed and Modeled Levels of Vehicle-Kilometers Traveled for Four OECD Study Countries**

SOURCES: For GDP per capita, Bolt and van Zanden, 2013; for VKT per capita, country-specific data sets as described in Appendix A.

Two additional points about this model are important. First, the adjusted R-squared value for this model is 0.985, indicating an extremely good fit. It is emphasized that this reflects a model assuming country-specific saturation ( $\gamma$ ) and growth ( $\beta$ ) terms. When we attempted to develop a model assuming generic growth ( $\beta$ ) terms, the resulting saturation levels were judged to be unsatisfactory. This suggests that, although GDP is a good predictor of automobility within one country—travel generally increases with GDP—it is far less relevant for forecasting the differences in automobility across countries. The long-term data series in Figure 6.5 shows that the level of VKT per capita at a given level of GDP per capita is too varied to be useful across countries. The different slopes of the models suggest that the speed of growth also differs across the countries and may depend on other country characteristics.

Second, the saturation levels in Figure 6.5 are long-term levels; they are not associated with a particular point in time or a specific income level. In the case of the United States and Australia, the model suggests that these countries are near saturation already. In the United States, current per capita VKT would need to grow by 17.3 percent to reach the estimated saturation (at its peak, U.S. VKT per capita was 15,031, which would have meant growth of only 8.5 percent). In Australia, the forecasted saturation level is only 4.7 percent higher than

current VKT per capita. Germany and Japan are currently much lower than forecasted, suggesting that further growth in per capita VKT may be anticipated. Reaching forecasted saturation levels from today's base VKT per capita would require 30.5-percent growth in Germany and 59.5 percent in Japan. However, it is emphasized that, although the model fit is good, these estimates are based on a model with only three parameters and are therefore subject to error and uncertainty.

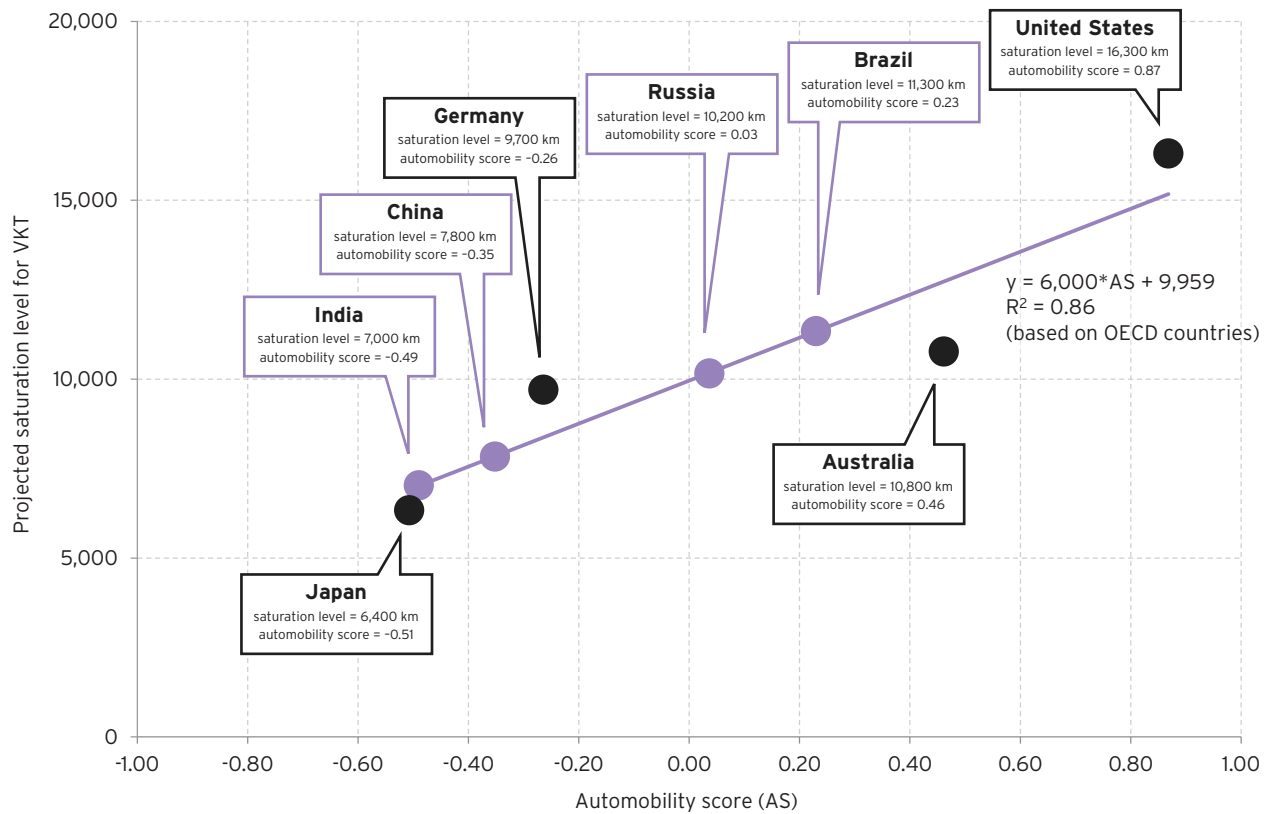
Next, we examined how well the automobility scores derived from expert elicitation for each OECD country explained the forecasted saturation levels. On a simple scatter plot, there appeared to be a linear relationship; that is, as the automobility score rose, so did a country's estimated saturation level. We fitted a linear regression model to these four data points, testing three different assumptions in deriving the automobility score:

- › The weights at the beginning of the motorization period were assumed to be twice as important as at the end of the motorization period.
- › The weights were equally important at the beginning and end of the motorization period.
- › The weights at the end of the motorization period were twice as important as at the beginning of the motorization period.

The model fit for all models was high, although we again emphasize that the models reflect only four observations. Moreover, the regression analysis did not indicate that the explanatory power of the model increases when either the beginning or the end of the motorization period is given greater weight, although we note that this finding may be limited by the small number of data points. We therefore adopted the model that assumed equal weights across the motorization period. This model fit the data well, with an adjusted R-squared value of 0.86, which means that 86 percent of the variation in saturation levels in Figure 6.5 can be explained by the automobility scores based on our nine factors (assuming that the factors have equal weight at the beginning and end of the motorization period).

Given that our assumptions about the influence of other factors on saturation levels seems to be supported, our last step was using this information to forecast future saturation levels in the BRIC countries. We put the automobility score for each BRIC country into the regression model equation calibrated by the OECD countries. If the nine factors influence the BRIC countries similarly to how they influence the OECD countries, this model should provide us a reasonably good forecast of the BRIC countries' future VKT saturation. The results of this are shown in Figure 6.6.

Given the above discussion of long-term changes in the various factors, it is no surprise that we find varied levels of long-term per capita VKT among the four BRIC countries. India and China are in between the Japanese and German levels, while Russia is slightly higher than Germany, and Brazil is slightly higher than Australia.



**Figure 6.6. Automobility Scores and Forecasts of Long-Term Travel Saturation Levels**

NOTE: Rounded to nearest 100.

When we look at the four developed countries in our study, we see substantial differences in automobility and in forecasted saturation levels. Japan is expected to level off in terms of personal vehicle travel demand at 6,400 km per capita, compared with 9,700 km per capita for Germany, 10,800 km per capita for Australia, and 16,300 km per capita for the United States. Per capita VKT in Japan leveled off at about \$20,000 GDP per capita even though the economy continued to grow. However, in the other countries, particularly the United States, travel demand continues to grow and levels off at much higher levels of GDP per capita. These findings indicate the importance of factors other than economic growth in forecasting a country's future automobility.

India and China reach saturation at about the same level, between 7,000 and 8,000 km per capita (their VKT per capita were 92 and 381, respectively, in 2008). If this forecast proves accurate, long-term VKT saturation is headed to levels far closer to European levels than American ones, and Japan will continue to have the lowest VKT per capita. On the other hand, Russia reaches saturation at just over 10,000 km per capita, showing a pattern closer to Germany's. VKT per capita in Russia was 2,133 in 2008. The United States remains an outlier on the high end.

Brazil is estimated to have the second-highest saturation level of all eight countries—second only to the United States, although the gap between them is wide. VKT per capita was 1,136 in Brazil in 2008. Two factors are unusually high: the domestic car industry, which was expected to be far more important economically in Brazil than in the other BRICs, and pro-car policies. The only factor that was thought to have a major dampening effect was inexpensive fuel (that is, fuel prices would become more expensive relative to income). It is also true that Australia is a bit of an outlier, in that its estimated saturation level is lower than its automobility score suggests.

What causes these potential differences in saturation levels? Our study indicates that exogenous factors, such as whether the country has domestic oil or a growing car industry, can encourage or discourage automobility. Whether a country's urban areas are dense or sprawling can make a difference, as well as whether the country has in place transportation policies that discourage car travel and infrastructure that supports alternatives to driving. Although the exogenous factors are far less responsive to policy interventions, the link between VKT and GDP can be manipulated by levers associated with the policy factors of fuel price, pro-car policies, alternatives to driving, and, most significantly, car infrastructure.





**ОПАСНОСТЬ**

**DANGER**



# Chapter Seven

## Conclusions

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This project considered how factors other than economic growth that have influenced the mobility paths in developing countries might affect the mobility paths in countries that are now entering a period of rapid growth. To inform this question, we developed an approach that combined qualitative and quantitative analyses. Although the methodology we developed is based on a variety of assumptions and expert opinions, we believe that this work helps identify and explain the non-economic factors that have shaped mobility in developed countries. Our model suggests that these factors help explain the varying paths of mobility development, and, informed by this, we can make some interesting forecasts about the paths of mobility development and specifically about future levels of VKT in the BRIC countries.

In this chapter, we return to the three research questions in the introduction, draw additional policy implications, provide some thoughts on how our findings fit into the existing body of work in this area, and discuss ideas for future research.

## Relationship Between Factors and Automobility

This section summarizes the answers to the three research questions we sought to answer in the introduction.

### What Factors Besides Economic Development Affect Automobility?

Among the nine factors identified as influencing mobility in developed countries, two factors—car infrastructure and spatial dispersion—were identified as most significant. Lower average urban densities stimulate greater auto use, a relationship we see clearly in the much higher motorization rates of Australia and the United States during their motorization periods.

In addition, the state of a country's roadways, both in terms of quality and quantity (in center-line kilometers), significantly influences the demand for automobile travel. According to the case studies, this factor seems to have less of an influence in the beginning of the motorization period because the demand for good roads follows the demands of new vehicle owners for roads on which to drive. However, once a road network is in place and driving becomes the most convenient default mode choice, the availability of car infrastructure creates a path of dependence that can influence the later development of automobility. Our research confirms the findings from other studies that the built environment plays a key role in shaping people's transportation choices (for a review of recent studies, see Committee for the Study on the Relationships Among Development Patterns, Vehicle Miles Traveled, and Energy Consumption, 2009).

### How Can We Assess the Influence of These Factors?

We developed automobility scores to summarize the influence of factor conditions in each country during its motorization period, where the score for a totally auto-oriented country would be 2 and the lowest score would be -2. The scores for the developed countries ranged from a high of 0.87 for the United States to a low of -0.51 for Japan. Our analysis indicated that the United States was significantly influenced by policy and exogenous factors that encouraged automobility during its motorization period. From a policy perspective, the United States saw a large increase in car infrastructure and a lengthy period of inexpensive fuel, both of which foster automobility. It was also heavily influenced by suburbanization and sprawl. On the other hand, in Japan, tough regulation, urban density, good alternatives to driving, and historically limited car infrastructure created a context that discouraged automobility.

The BRIC country automobility scores ranged from positive scores of 0.23 in Brazil and 0.03 in Russia to negative scores of -0.35 and -0.49 in China and India, respectively. The BRIC country scores are obviously more speculative because the ends of their respective motorization periods are decades away. Brazil entered its motorization period earlier than the other BRIC countries and exhibits the most favorable factor conditions for automobility in terms of rising shares of the population that are active, pro-car policies, and the presence of a domestic car industry. Our analysis implies that Brazil will continue to develop in that direction and eventually have the second-highest saturation level of all eight countries. Russia, on the other hand, entered its motorization period in the 1990s, and the presence of domestic oil buoyed its development toward automobility. However, the analysis indicates that policies that favor personal vehicles and inexpensive fuel may not continue in the long term and will hinder growth in travel demand. China and India entered their motorization periods in the decades of the 2000s and 2010s, respectively, and so are in the position to significantly alter their paths toward automobility. Both countries have implemented policies to discourage automobility at the same time as more of their citizens have been able to afford personal vehicles.

## **What Will Happen to Automobility in Developing Countries If Those Same Factors Have Similar Influence?**

What does this say about future personal vehicle travel saturation in developing countries? Given the anticipated growth in GDP per capita for the BRIC countries, the ends of their respective motorization periods may be only a few decades away. Therefore, current conditions and those in the near-term future will have a major impact. Using our methodology, we forecast long-term saturation levels in China and India well below those in the United States (7,000 and 7,800 VKT per capita versus 16,300 VKT per capita). Russia and Brazil also reach saturation below the United States but at significantly higher levels than China or India: 10,200 and 11,300 VKT per capita, respectively. Many of the factors that influence car travel demand, especially the exogenous ones, change only slowly over time, and substantial growth in personal vehicle travel is likely to occur no matter what transportation policies are adopted.

There are, of course, myriad reasons that our forecasts of factor change and VKT may prove to be incorrect. Countries may choose not to invest heavily in car infrastructure. Fuel prices may rise substantially because of market forces. Factors not considered here, such as the need to control GHG emissions or seismic changes in travel patterns as a result of new technologies, may become more important than the factors we have considered here. However, although the factors themselves or the way they influence demand for automobility may change, we do think that it is important to incorporate factors other than GDP into forecasts of automobility.

## Policy Implications

In addition to the specific forecasts of automobility saturation in the BRIC countries, we find three broader policy implications.

- › First, income is not destiny. Most work in the area of long-range forecasting of automobility has used income as the primary or only variable. Although there is a strong correlation in the OECD countries between income growth and growth in vehicle travel (both per capita and total), income levels alone are not good predictors of travel demand. We see this in the wide range of current levels of VKT per capita in the OECD countries, and we anticipate that the same will be true for the BRIC countries as well.
- › Second, the results of this work seem to confirm our hypothesis that understanding economic growth is quite helpful in understanding changes in demand for automobility over time within one country but far less so in understanding variability in demand between countries. To more fully understand the differences between countries, we need to include other factors. Although further research may suggest refinements to the nine factors used in this analysis, it seems clear that relying exclusively on income in international comparisons has less explanatory power than a method that incorporates additional factors.
- › Third, the experts identified spatial dispersion and car infrastructure as the most important of the nine factors. In addition, we identified other means available to policymakers to influence demand, such as transportation policies that keep consumer prices for fuel more expensive than the market price, discourage excessive driving, and encourage alternatives to driving. This suggests that policymakers can steer some elements of travel demand if desired. Although rising incomes tend to encourage driving, this can be countered by other policy measures; especially in developing countries, where infrastructure and spatial patterns are still being developed, there are opportunities to dampen the demand for driving.

Of course, there are still influential exogenous factors, such as oil prices, that are not under the direct control of policymakers, and demand responds to those as well. But our findings suggest that policymakers have some capacity for action in this area.

## Relevance with Regard to Existing Work

This study took an innovative approach that combined quantitative and qualitative methods to estimate future VKT per capita. Although many researchers treat VKT forecasts as a purely quantitative question and develop sophisticated models to derive forecasts, such models are often limited. They can include only factors that are measurable with historical data, so they tend to include only a small number of factors. Many of the prior studies thus focus heavily on GDP per capita as the main predictor of mobility, with some representation of infrastructure and spatial dispersal (see, for example, Schafer and Victor, 2000).

In contrast, the approach used in this study takes into account of a wider range of factors, including harder-to-measure ones, such as car culture. Additionally, relative to developing a traditional travel demand model, this study's method is substantially less resource-intensive. Model development often necessitates multiyear effort by large research teams, whereas an expert-based approach can be completed in months' time, especially because the postworkshop opinion-elicitation process can be expedited and completed through email.

The approach used in this study also differs from convention Delphi studies, in which experts are asked to make predictions about the outcome of interest directly (see, for example, Ewing and Bartholomew, 2009). Instead, in this study, we asked experts to focus on estimating the state of factors underlying the outcome and used those as the inputs for a more quantitative analysis.



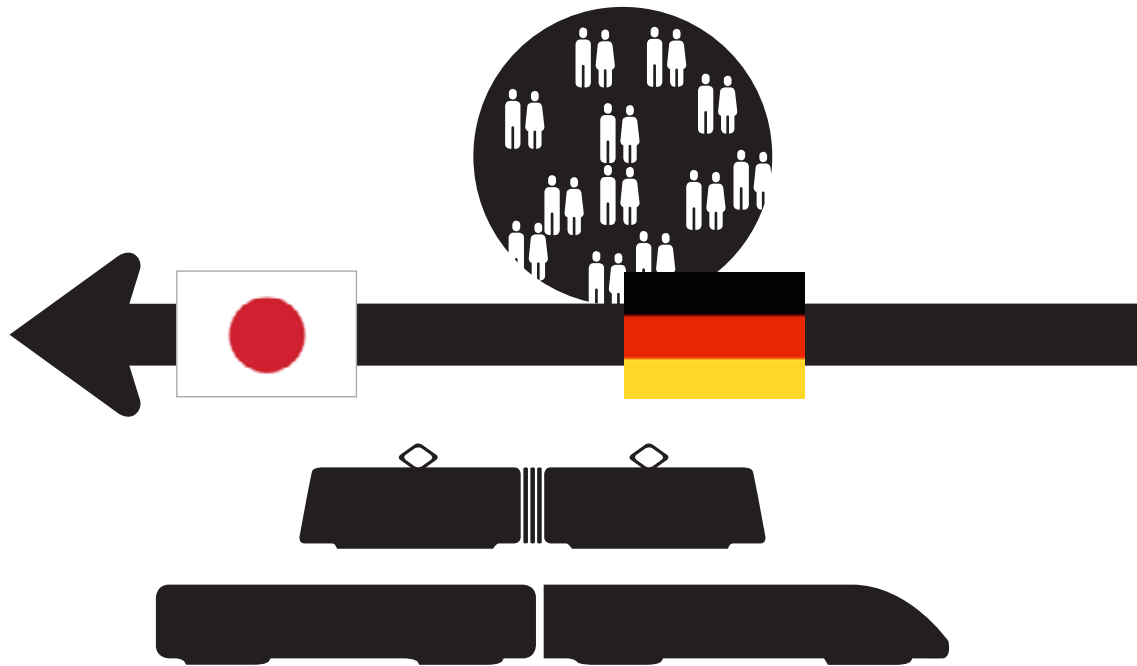
## Suggestions for Future Research

This work could be extended in six ways:

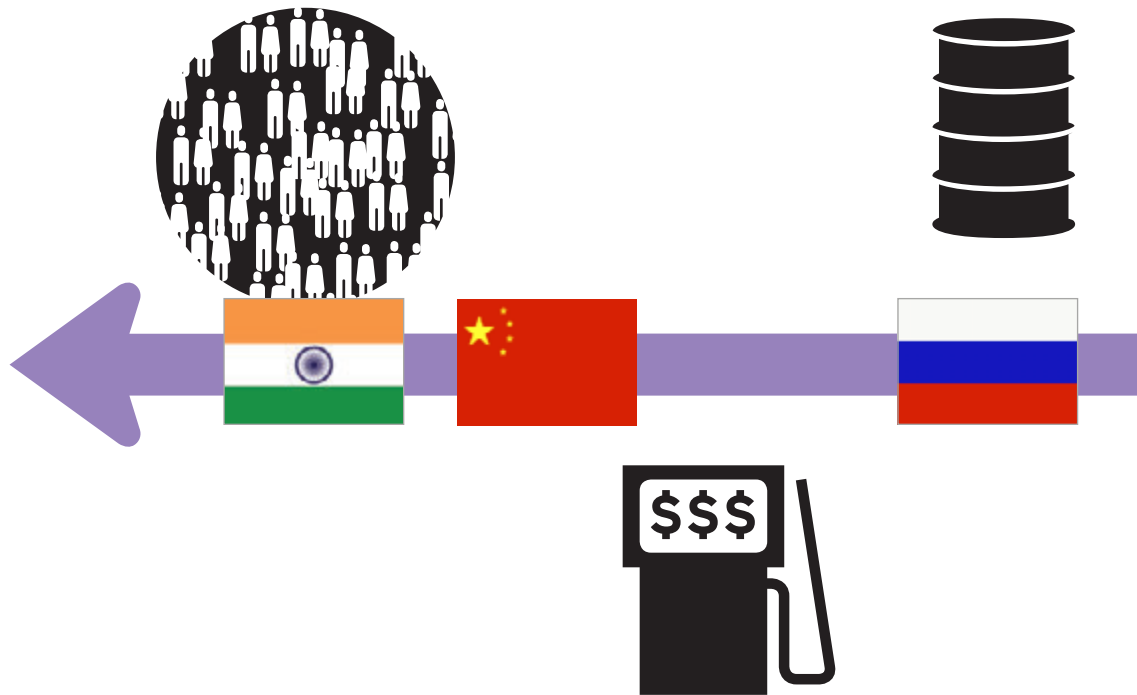
- › by quantifying the VKT growth rates in the BRIC countries. The study quantified saturation levels for personal vehicle travel for the BRIC countries, so the obvious next step would be quantifying the path to reach these saturation levels by estimating the speed of VKT growth. As Figure 6.5 in Chapter Six shows, the rates of growth do differ between the four OECD countries, although not to the same extent as differences in saturation rates. Moreover, when we used a single generic growth term for the four countries, we found the resulting saturation levels to be much less reasonable. Given what we know about the growth rates in the OECD countries, we could examine how different growth assumptions influence the shape of the S-curve of mobility evolution for the BRIC countries. That is, we could use both the U.S. growth rates and the Japanese growth rates to estimate the various rates at which Chinese growth in VKT might occur.
- › by conducting sensitivity analysis on the existing factors. The saturation levels we estimated are based on two important assumptions: (1) saturation levels for the OECD countries are linked to non-economic factors identified by experts and (2) these relationships will hold true for the BRICs. We could explore the sensitivity of growth rates to assumptions about the level of the non-economic factors provided by experts by varying the factor scores provided for these countries. For example, would Australia be less of an outlier if expert opinion found a much lower level of car-culture favorability or pro-car policies at work? Some of the past assessments of factor scores were based on quantifiable data, but others were based largely on expert judgment, as are all of the future forecasts for the BRICs. It would be useful to know how robust this methodology is to alternative opinions about the factors.
- › by changing the factor mix. This might include testing additional factors, which might add more explanatory power, or removing those factors that seem to have a less important influence. For example, we could look at whether population density for the whole country seems to have an impact on automobility.
- › by expanding the set of countries. The basis for determining the saturation levels rests on data from only four countries, two of which are distinct outliers among the developed countries in terms of their unusually high (United States) and low (Japan) levels of VKT per capita. An analysis of a larger set of countries, or a set that represents more typical evolutionary paths, might yield a different result when regressing the automobility scores on the estimated saturation levels, which would, in turn, change the forecasted levels in the BRIC countries.
- › by looking at forecasted mobility in other developing countries that are beginning to motorize. Employing this methodology would require similar convening of an expert panel consisting of representatives from the study countries; we are not aware of existing data sources that would yield reliable results. Indeed, collection of relevant and comparable data was difficult for the OECD countries, so we do not think it would be any easier for developing countries.

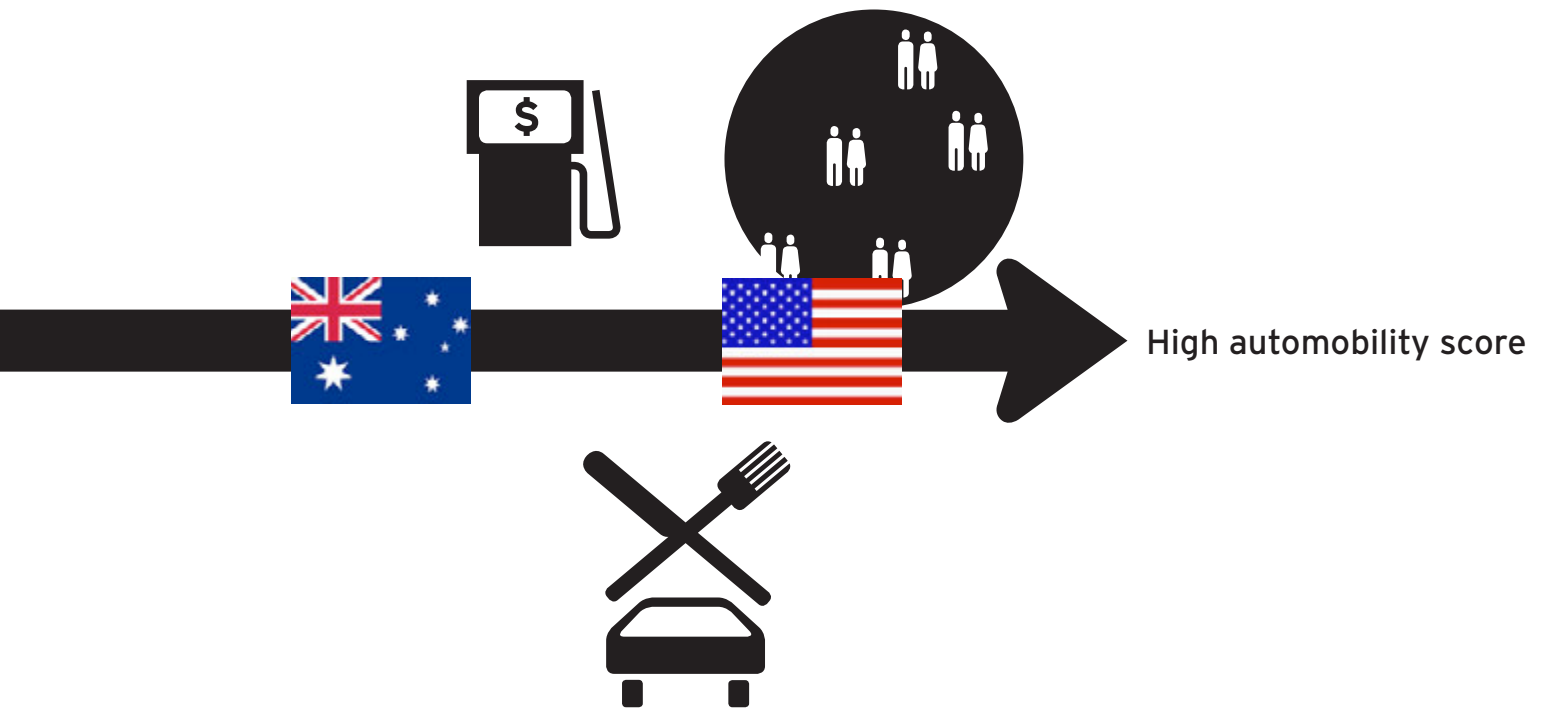
› by looking at saturation levels in vehicle ownership or even other forms of mobility. We considered both of these approaches as part of this project, but, given the difficulty of collecting data, we decided to focus exclusively on VKT as the only measure of mobility. However, with appropriate data, we think that the methodology developed here would be helpful for addressing those other mobility topics as well.

Low automobility score



Low automobility score





**Figure 7.1. Conclusions**  
SOURCE: Institute for Mobility Research.

**Garagem**



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Estaciona**



# Appendix A Data Sources

Although all data sources are provided in the reference list, this appendix explains how we created these specific data sets that were used for the analysis.



## GDP Per Capita

For all countries, GDP per capita figures were derived from Bolt and van Zanden (2013), who have recently updated the work of Maddison (2010a). Maddison assembled a set of GDP per capita figures, dating back a century or more in some cases, that are based on conversion using PPP as opposed to exchange rates. These figures use a particular conversion developed for international comparisons called Geary-Khamis dollars. Essentially, this conversion method removes the fluctuations that arise based on changes in currency conversion rates and thus better reflects their purchasing power in their relative countries. This makes them a more useful way to compare GDP not only across countries but also over time than data series that are denominated in U.S. dollars and adjusted based on annual currency conversion rates. The Geary-Khamis dollars in this data set are indexed to 1990.

The original Maddison (2010a) data set ended in 2008, and it contained the most recent data available as we were developing the two-by-two tables for country selection. However, Bolt and van Zanden have since extended the data series through 2010. Because our earlier work was based on 2008 data, we kept that as the analysis year, especially because not every country had vehicle ownership and VKT per capita data available through 2010. However, when updating the tables for this report, we used the revised 2008 figures in Bolt and van Zanden.

## Vehicle Ownership and Vehicle-Kilometers Traveled Per Capita

For all countries, we looked for data sources that reflected vehicles commonly used as personal vehicles. Although many countries go through a stage during which motorcycle ownership is high, we ultimately decided to focus, to the extent possible, on four-wheeled vehicles because motorcycles are not always included with other vehicle ownership statistics. Also, they may be conflated with other types of motor vehicles, such as motor scooters, with different licensing requirements.

For all countries except the four OECD case-study countries, we used data available through ProgTrans as the source for both vehicles per 1,000 people and VKT per capita. ProgTrans, an independent commercial company, compiles data on vehicle ownership and VKT. Data are available only from 1995 forward. ProgTrans was selected for the stage of the project in which we were identifying study countries and thus needed a data source with multiple countries. In addition, ProgTrans data contained fewer discrepancies, such as jumps in the data, that made other sources problematic.

For the four case-study countries, we used national data sources that were obtained from various transportation and statistics agencies, as described in the rest of this section.

## Australia

Australian data on VKT and vehicle ownership from 1963 onward were obtained from the Australia table in Appendix B in BITRE (2012b, pp. 212-213). Vehicle ownership for 1900 to 1962 was extrapolated from Knott (2000, Figure 1). Population data were obtained from BITRE (2012b, pp. 196-197).

## Germany

For Germany, we used VKT data from the Verkehr in zahlen (ViZ, or transport in figures), an annual report compiled by the Deutsches Institut für Wirtschaftsforschung ("German Institute for Economic Research") in Berlin on behalf of the German Ministry of Transport, Building and Urban Development (Deutsches Institut für Wirtschaftsforschung, 2011). These VKT data include West Germany through 1990 and unified Germany beginning in 1991. For vehicle ownership, we combined ViZ figures (Deutsches Institut für Wirtschaftsforschung, 2011) with data from Kraftfahrt-Bundesamt (KBA, or Federal Motor Transport Authority) (2011) and Destatis (Federal Statistical Office) (undated [b]). We used ViZ data for vehicle ownership from 1950 to 1980 (Federal Ministry of Transport, Building and Urban Development, 1991) and KBA data for 1981 to 2011 because the available ViZ data ended in 2009. The vehicle ownership data include West Germany through 1992, even though reunification took place in 1990.

The vehicle ownership statistics had to be manipulated slightly. Before 2008, vehicles that were temporarily deregistered (e.g., a vehicle without a license plate in a car dealership) were contained in the official registration statistics; from 2008 onward, they were dropped. This created a 10-percent drop-off between 2007 and 2008 in the official vehicle ownership statistics. Between 1998 and 2008, the ratio of all registered cars (including temporarily deregistered cars) to registered cars (without temporarily deregistered cars) was stable at 1.13. For consistency over time within the German time series, the German figures for passenger-car registration from 2008 onward were multiplied by 1.13 (that is, temporarily deregistered cars were imputed into the statistics for the time after 2008).

Population data to create per capita figures are from Destatis (undated [b]), with data beginning in 1950.

## Japan

For Japan, most data were obtained from the Japan Statistics Bureau. For vehicle ownership, figures through 2004 were obtained from the Historical Statistics of Japan, Table 12-10 (Japan Statistics Bureau, 2012b). Later years were obtained from the 2010 and 2012 Japan Statistical Yearbook (Japan Statistics Bureau, 2010, 2012a), Table 12-5 in each. Vehicle ownership includes total passenger cars and light motor vehicles (軽自動車), a category in Japan for very small cars that are not registered as passenger cars.<sup>1</sup>

VKT from 1950 through 2004 was obtained from Table 12-12-a, Historical Statistics of Japan (Japan Statistics Bureau, 2012b). For 2005 to 2009, we obtained data directly for individual years from the Ministry of Land, Infrastructure, Transport, and Tourism, Road Transport Bureau, Motor Vehicle Transport Statistical Yearbook (Japan Ministry of Land, Infrastructure, Transport, and Tourism, 2006, 2007, 2008, 2009, 2010), Table 3-1-1.

Population figures were obtained from Historical Statistics of Japan (Japan Statistics Bureau, 2012b), Tables 2-2 and 2-3.

<sup>1</sup> Light motor vehicles can have an engine up to 660 cubic centimeters; have a body up to 3.48 m long, 1.48 m wide, 2 m tall; and carry a maximum of four passengers, including a driver, and up to 350 kg in cargo (T. Yamamoto, 2012b).

## United States

For the United States, we combined data from several sources to create a data series on personal vehicle ownership that includes both cars and light-duty vehicles. We felt that this was important because light-duty trucks have become increasingly popular as personal vehicles. A data set based only on cars would provide a misleadingly low number of personal vehicles per 1,000 people. However, changes in definitions required obtaining data from two sources. For 1963 to 1995, we used data from two tables in Highway Statistics Summary to 1995 (FHWA, 1995): Table VM-201A (data on passenger cars, a category that includes motorcycles; and other two-axle, four-tire vehicles) and Table MV-201 (motorcycle data) for 1963 to 1995. Motorcycle ownership data were required because we wanted to subtract motorcycle ownership from the data in Table VM-201A. For the period from 1996 to 2008, we used Table 1-11 (light-duty vehicles with both short and long wheel bases) in the National Transportation Statistics (BTS, undated).

For VKT per capita, we used a similar method. For 1963 to 1995, we used VMT for passenger cars and other two-axle, four-tire vehicles available in Table VM-1 (FHWA, 1995). For 1996 to 2008, we used Table 1-35 in BTS (undated). These data sets include VMT driven on motorcycles because FHWA (1995) did not separate out VMT driven on motorcycles and we wanted to change the definition of VMT to be consistent. The VMT were converted to VKT.

Both were transformed into per capita figures based on two census sources: For data for 1963 through 1999, we used "Historical National Population Estimates" (U.S. Census Bureau, 2000); for 2000 through 2008, we used "Table 1, Annual Estimates of the Resident Population for the United States, Regions, States, and Puerto Rico: April 1, 2000 to July 1, 2009" (U.S. Census Bureau, 2009).

## Fuel Prices

We used both international and national sources to compile a data set for historical fuel prices. For each country, we developed a ratio of the cost of 1 liter of gasoline as a percentage of average daily income. As a proxy for average daily income, we divided total annual GDP in current (that is, not adjusted for inflation)<sup>2</sup> local currencies by population and by 365 days in a year. For three countries, we used data sets available through the Measuring-Worth project: for the United States, Williamson (undated); for Japan, Officer and Williamson (2012); and, for Australia, Hutchinson (undated). For Germany, we used per capita GDP figures from Destatis (undated [a]).

We used the following national sources for fuel prices:

- › Australia: BITRE, 2012a, Table A5. Fuel prices were not available on a national basis; these figures average the retail prices from provincial capital cities (Sydney, Melbourne, Brisbane, Adelaide, Perth, and Hobart for the period 1955-1964, with the addition of Darwin and Canberra from 1965 onward). Data were available on a quarterly basis; we used them to compute a yearly average.
- › Germany: Deutsches Institut für Wirtschaftsforschung (2011) for all years.
- › Japan: Statistics were available only for Tokyo,<sup>3</sup> not the entire country. For 1946 to 1965, retail prices of gasoline were provided by Toshiyuki Yamamoto (2012a). For 1966 onward, we used Japan Statistics Bureau (2012b, Table 22-19).
- › United States: Retail gasoline prices in current dollars per gallon for 1950 to 2004 are from the Vehicle Technologies Office, Energy Efficiency and Renewable Energy at the U.S. Department of Energy (2005). Retail gasoline prices in current dollars per gallon since 2005 are from EIA (2012, Table 5-24 [average for all areas]).

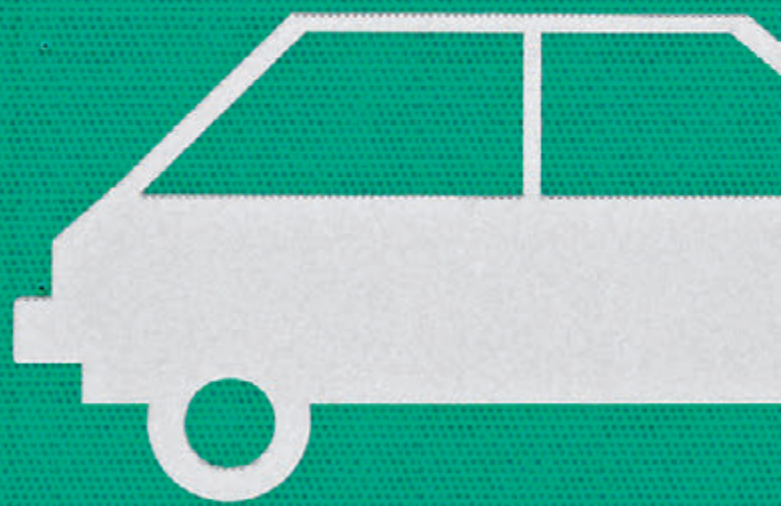
<sup>2</sup> Hutchinson (undated) uses the term nominal GDP, which has the same meaning.

<sup>3</sup> Specifically, the figures are for the 23 wards that are considered Tokyo proper, as opposed to the larger metropolitan area.



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# Appendix B Country Travel Demand Experts

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Table B.1 lists the travel demand experts by country who participated in the April 2013 workshop in Berlin.

Table B.1. Country Travel Demand Experts

Country	Expert Name	Affiliation
Australia	Jeffrey R. Kenworthy	University of Applied Science, Frankfurt am Main
Brazil	Luiz Afonso dos Santos Senna	Federal University of Rio Grande do Sul, Porto Alegre
	Antonio Nelson Rodrigues da Silva	University of Sao Paulo
	Emilio Merino Dominguez	Federal University of Rio Grande do Sul, Porto Alegre
China	Lu Huapu	Tsinghua University, Beijing
Germany	Uwe Kunert	German Institute for Economic Research, Berlin
Japan	Toshiyuki Yamamoto	Nagoya University
India	Ashish Verma	Indian Institute of Science, Bangalore
	Senathipathi Velmurugan	Central Road Research Institute, Delhi
	Subhamay Gangopadhyay	Central Road Research Institute, Delhi
Russia	Konstantin Trofimenko	Moscow State Automobile and Road Technical University
	Yelena Koncheva	Institute for Transport Economics and Transport Policy Studies, National Research University Higher School of Economics, Moscow
	Yegor Muleyev	Institute for Transport Economics and Transport Policy Studies, National Research University Higher School of Economics, Moscow
United States	Johanna Zmud	RAND Corporation, Arlington, Virginia







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# Appendix C

## Factor Fact Sheets and Flag-Game Results

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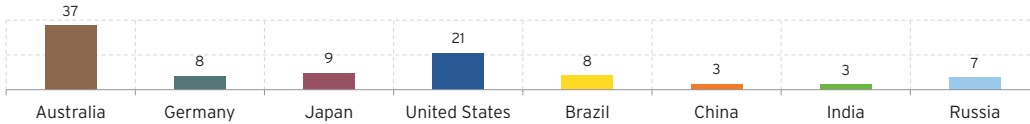
This appendix provides the fact sheets and flag-game results from the April 2013 workshop in Berlin. For each fact sheet, information provided for the OECD countries is from published sources or based on the synopsis of each country in Chapter Four. Information for the BRIC countries was provided by the experts in the workshop.

## Good Car Infrastructure

This factor is made up of all infrastructure for automobility, including the quality and quantity (in center-line kilometers) of roads and parking supply.

### Fact Sheet and Expert Observations

Total road network (center-line meters per population), 2008-2011



#### OECD countries

##### Australia:

- Road infrastructure is extensive but includes a large share of unpaved roads.

##### Germany:

- The first autobahn was finished in 1932, part of extensive investment in roads in the 1930s to 1950s.
- There was a second wave of road investment in 1960s West Germany.
- There is limited parking supply.

##### Japan:

- There were few paved roads even in the 1950s but massive investments in road building in 1960s and 1970s.
- There is very limited parking infrastructure.

##### United States:

- The good-roads movement started in 1880s.
- There were major roadway investments in the 1920s, and interstates were built in the 1950s and 1960s.
- There is substantial parking supply.

#### BRIC countries

##### Brazil:

- There is good overall road penetration, but quality and quantity in urban areas are deficient.
- In recent years, congestion levels have increased massively.

##### China:

- The road network has extended rapidly.
- The extension has taken place mostly in small cities, where space is available.

##### India:

- There are insufficient parking arrangements in Indian cities, but the situation is expected to improve because of construction.
- There is also notorious chaos resulting from congestion, but facilities are improving over time.

##### Russia:

- Recently (and in the midterm future), there has been substantial investment in road infrastructure.

### Factor Scores

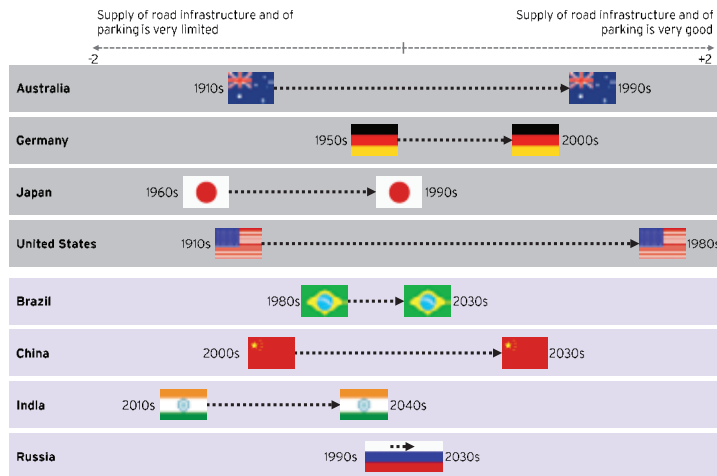


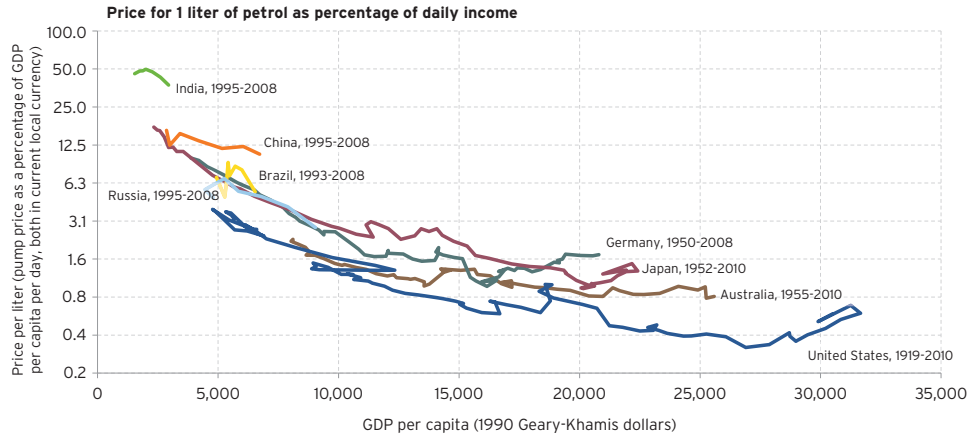
Figure C.1. Fact Sheet, Expert Observations, and Factor Scores: Good Car Infrastructure



## Inexpensive Fuel

This factor describes whether fuel is inexpensive relative to income. Fuel price refers to the pump price, which includes all taxes and fees.

### Fact Sheet and Expert Observations



#### OECD countries

- Australia: 2010 tax share in gasoline cost was ~40%.
- Germany: 2010 tax share in gasoline cost was ~60%.
- Japan: 2010 tax share in gasoline cost was ~50%.
- United States: 2010 tax share in gasoline cost was ~20%.

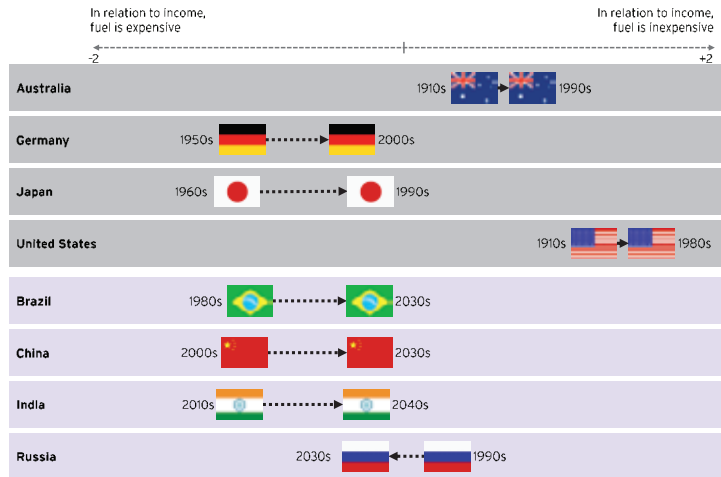
#### BRIC countries

- Brazil: Taxation on fuel is relatively high (among the highest in South America); diesel is subsidized.
- China: Fuel taxation is moderate.
- India: Diesel is subsidized; gasoline is taxed at about 55%.
- Russia: Gasoline is currently taxed moderately, but taxes will increase.

SOURCES: For gasoline price, Australia, BITRE, 2012a; Germany, Deutsches Institut für Wirtschaftsforschung, 2011; Japan, 1946-1965, T. Yamamoto, 2012a; Japan, 1966-2011, Japan Statistics Bureau, 2012b, Table 22-19; United States, 1919-2004, Vehicle Technologies Office, 2005; 2005-2012, EIA, 2012, Table 5.24; BRIC countries, Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH, 2012. For GDP, Australia, Hutchinson, undated; Germany, Destatis, undated (a); Japan, Officer and Williamson, 2012; United States, Williamson, undated; BRIC countries, World Bank, 2013.

Figure C.2. Fact Sheet, Expert Observations, and Factor Scores: Inexpensive Fuel

### Factor Scores





## Pro-Car Policies

This factor is made up of noninfrastructure policies and regulations regarding personal vehicle ownership and use. This ranges from vehicle taxes (except fuel tax, which is included in fuel costs) to vehicle inspection regulations to car usage fees (tolls) and city access restrictions.

### Fact Sheet and Expert Observations

#### OECD countries

##### Australia:

- Tax policies around salary packages encourage driving.
- Australia pioneered the use of graduated driver's licenses.

##### Germany:

- Tax policies in the past were rather car-neutral.
- Germany introduced pedestrianized areas early on.
- Parking management is commonplace.
- There are environmental zones.

##### Japan:

- In the past, there has been government support for buying cars.
- Today, tough vehicle inspection leads to high fleet turnover.
- Taxes on car ownership are high.

##### United States:

- There was little regulation in the past.
- Funding allocation historically favored roads over transit.
- Today, there are stricter CAFE standards.

#### BRIC countries

##### Brazil:

- Government policies are clearly pro-automobile.
- Import duties on cars are high (35%).
- The temporary reduction of taxes in 2012 has favored car sales.

##### China:

- In landmark cities, there are restrictions on car access, use, and ownership.
- Electric vehicles are promoted.
- Import duties on cars are high (25%).
- Highway use is free during holidays.

##### India:

- Import duties on cars are high (60-100%).
- Because of environmental concerns and the lack of energy, there are active policies to curb and regulate car-based mobility.

##### Russia:

- There has been little regulation of car use in the past but a recent introduction of car-related regulation, e.g., environmental zones.
- Until recently, there was no tax.
- Free parking is commonplace.

### Factor Scores

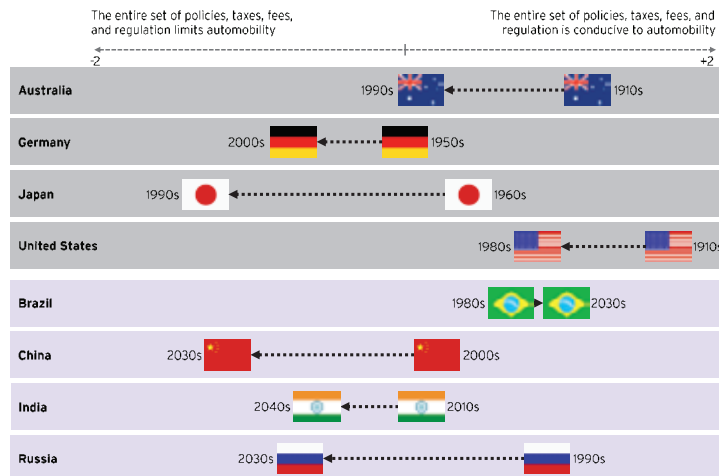


Figure C.3. Fact Sheet, Expert Observations, and Factor Scores: Pro-Car Policies

## Lack of Alternatives to Driving

This factor describes the supply of alternative modes of transportation in terms of amount and quality.

### Fact Sheet and Expert Observations

#### OECD countries

##### Australia:

- The world's largest streetcar network is in Melbourne.
- A large rail network connects capital cities.

##### Germany:

- There is substantial supply of public transport infrastructure with high quality in urban areas.
- Nonmotorized modes (e.g., bike lanes, traffic calming) are promoted.

##### Japan:

- There is an extensive intercity high-speed rail network.
- The world's largest train station is at Shinjuku.

##### United States:

- Streetcar systems that once existed in most large and medium cities were dismantled almost everywhere.
- Transit has long had a reputation of provision of mobility for those who had no other choices.
- Intercity rail is almost irrelevant.

#### BRIC countries

##### Brazil:

- There is hardly any passenger-rail traffic.
- There have been substantial transit investments for the World Cup in 2014 and Olympic games in 2016.

##### China:

- There have been massive investments in public transport infrastructure.
- Length of dedicated lanes for transit has increased.

##### India:

- Although, in Delhi and Mumbai, urban rapid transit (metro rail and other) has been installed, urban rapid transit is generally in its infancy but developing in Indian cities.

##### Russia:

- There is an existing heritage of transit from the Soviet era, e.g., the largest number of tram networks in the world.
- Currently, the quality is deteriorating, and, in the past 20 years, trams have been dismantled and the number of cities with trams has reduced from 70 to 62. However, substantial investments are imminent, and that will turn around the development.

### Factor Scores

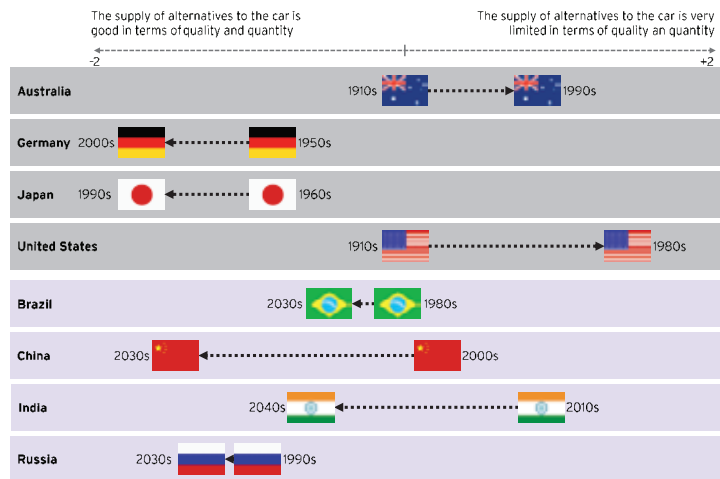


Figure C.4. Fact Sheet, Expert Observations, and Factor Scores: Lack of Alternatives to Driving

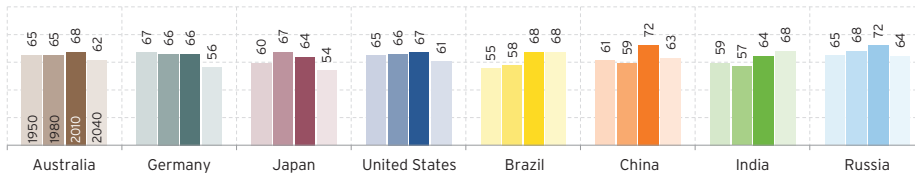


# Active Population

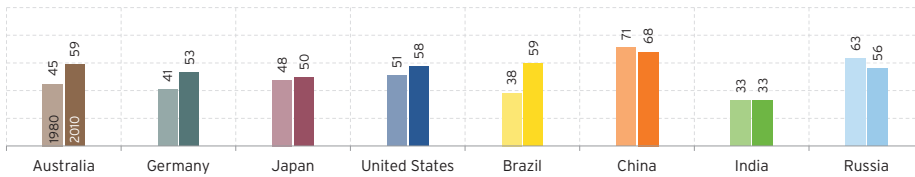
This factor describes the share of population in a life situation with high mobility rates. This includes both demographic effects (i.e., age cohorts in which mobility is typically high) and workforce participation (i.e., the share of the working-age population who work, e.g., female labor-force participation).

## Fact Sheet and Expert Observations

Working age (15-64) population as a percentage of the total population



Female labor-force participation rate (percentage of the female working-age population who work)



### OECD countries

- Recent decades: relatively high shares of active population due to demographic setup (baby boomers moved into the working age) and mostly increasing workforce participation of women.

### BRIC countries

- The status quo is high (in China and Russia, very high) shares of the population who are between 15 and 64 and very high workforce participation of women, except in India.
- The future projection is that, demographically, the share of the population in active age groups will decrease (except in India). Labor-force participation of women is expected to increase in all BRIC countries.

SOURCES: For working-age population as a percentage of the total population, OECD, undated. For female labor-force participation, World Bank, 2013.

## Factor Scores

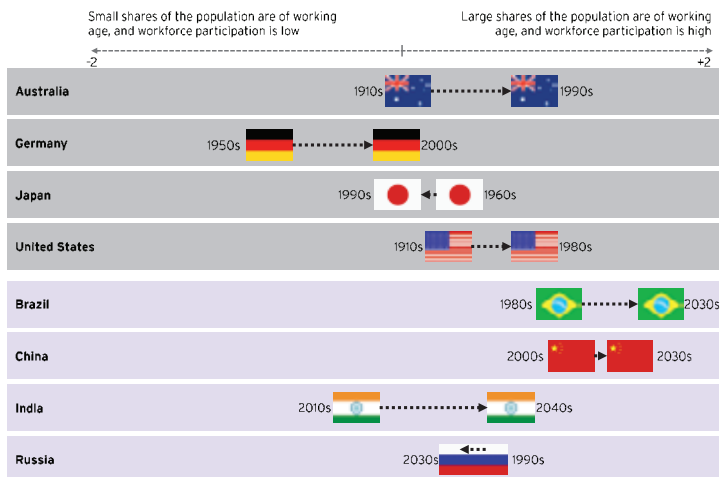


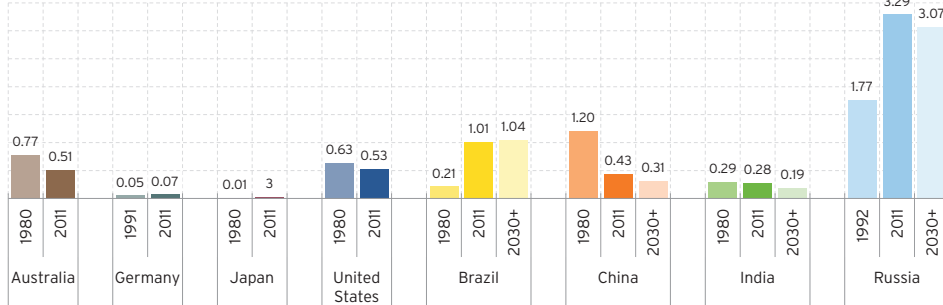
Figure C.5. Fact Sheet, Expert Observations, and Factor Scores: Active Population

## Existence of Domestic Oil

This factor describes whether fuel is inexpensive relative to income. Fuel price refers to the pump price, which includes all taxes and fees.

### Fact Sheet and Expert Observations

Production-to-consumption ratio



#### OECD countries

- Australia: Since 1980, consumption has doubled but production has only slightly increased.
- Germany: Since 1991, little change in both consumption (slight decrease) and production (slight increase).
- Japan: Since 1980, consumption has slightly decreased but very low production has grown threefold.
- United States: Since 1980, consumption has grown but production fell until 2005 (recently again up to 1980 level).

#### BRIC countries

- Brazil: Since 1980, consumption has doubled and production has increased tenfold; the projected production increase is 40%.
- China: Since 1980, consumption has increased fivefold and production doubled; the projected production increase is 20%.
- India: Since 1980, both consumption and production have increased fivefold; the projected production increase is 30%.
- Russia: Since 1980, consumption has dropped 30% and production has increased 25%; the projected production decrease is 5%.

SOURCES: For crude-oil production and consumption for 1990 and 2011, EIA, undated. For petroleum production for 2030, EIA, 2013, Table G-1 (reference case). For liquid consumption for 2030, EIA, 2013, Table A-5 (reference case).

NOTE: Projections through 2030 were generated with EIA consumption projections and expert production projections.

### Factor Scores

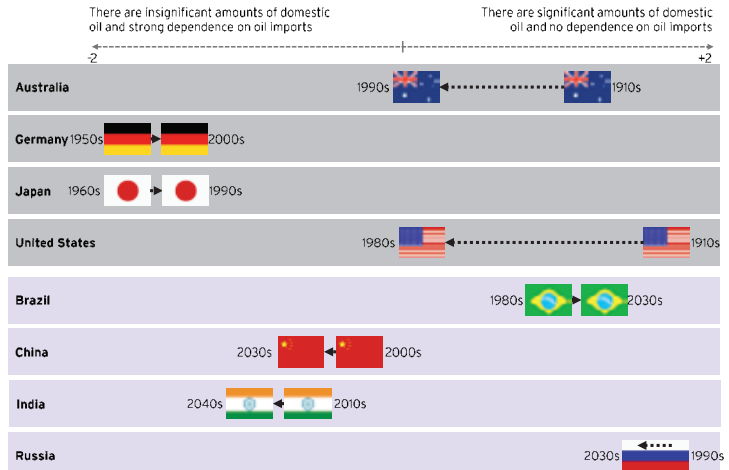


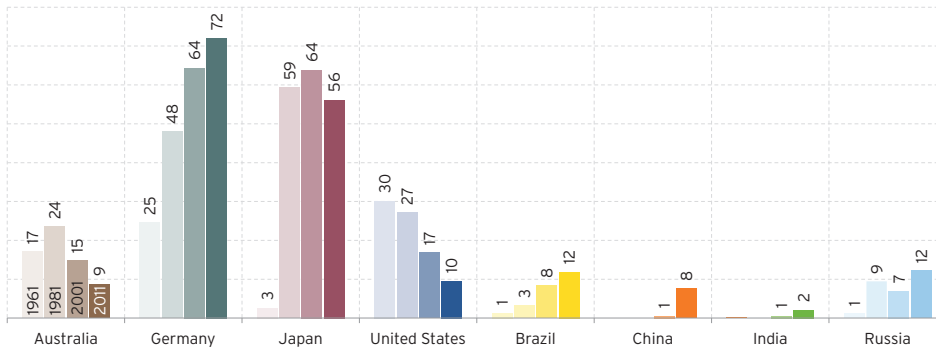
Figure C.6. Fact Sheet, Expert Observations, and Factor Scores: Existence of Domestic Oil

## Strength of the Domestic Car Industry

This factor describes the relevance of a domestic car industry for the national economy and the country's policies.

### Fact Sheet and Expert Observations

Number of passenger cars produced per 1,000 population



#### OECD countries

- Australia: In total number, relatively few cars were produced.
- Germany: There is a strong auto industry with an important domestic market and a focus on luxury cars.
- Japan: There was policy support for the early auto industry; the car industry is aimed at exporting.
- United States: The United States was the first to implement mass production of cars; despite the long decline of the importance of the auto industry, it remained the world's largest producer until 2009.

#### BRIC countries

- Brazil: There are pro-automobile government policies, e.g., with temporary tax reductions to fuel car sales.
- China: World's largest car producer since 2009; production for domestic market; growth will continue.
- India: Restrictive policies may curb production for the domestic market in the future; there is promotion of the auto-supply industry for export.
- Russia: There will be government support for growing car industry in the future. Russian-made cars dominate the local market.

SOURCES: For passenger-car production, BTS, undated, Table I-23 (updated October 2012). For population, U.S. Census Bureau, 2013.

### Factor Scores

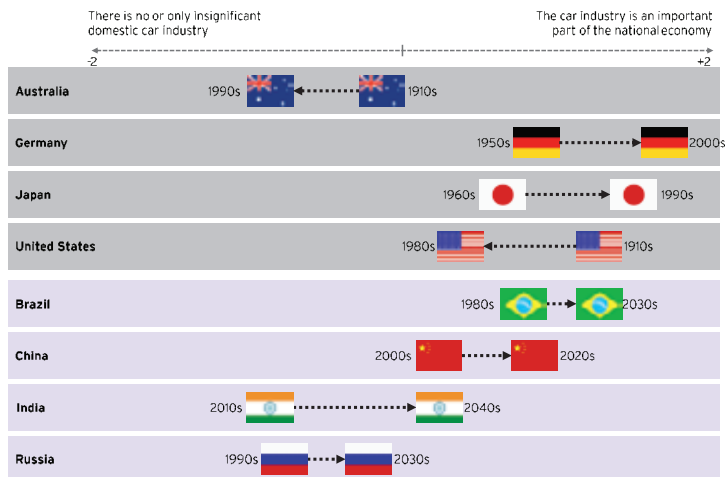


Figure C.7. Fact Sheet, Expert Observations, and Factor Scores: Strength of the Domestic Car Industry

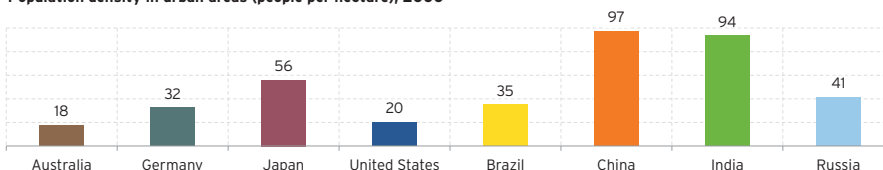


## Spatial Dispersion

This factor describes to which degree settlement patterns require motorized transportation. This includes both the proportion of people who live in urban environments and urban densities (population and jobs).

### Fact Sheet and Expert Observations

Population density in urban areas (people per hectare), 2000



#### OECD countries

##### Australia:

- Australia has sprawled metropolises.
- It has streetcar cities with early and extensive sprawl.
- 86% of dwellings are single-family houses.
- 58% of people live in agglomerations of more than 1 million.

##### Germany:

- Germany has compact, medium-sized cities.
- Urban fabrics were shaped in the nonmotorized era.
- Post-World War II years brought urbanization and dense suburbanization.
- 45% of population live in single-family houses.

##### Japan:

- Japan has dense megacities.
- There was very early urbanization in dense cities.
- 49% of people live in agglomerations of more than 1 million.

##### United States:

- The United States is sprawled and spread out.
- Urban fabrics were shaped by the streetcar and auto.
- Suburbanization and sprawl came very early and strong.
- 70% of dwellings are single-family houses.

#### BRIC countries

##### Brazil:

- Urbanization is high.
- 41% of people live in agglomerations of more than 1 million.

##### China:

- 18% of people live in agglomerations of more than 1 million.
- Compact and high-density cities are promoted.
- Lack of land will keep densities high.

##### India:

- The rural population is still a very large share of the total population.
- 13% of people live in agglomerations of more than 1 million.

##### Russia:

- 18% of people live in agglomerations of more than 1 million.
- Urbanization is increasing, but urban sprawl with single-family housing is less common than in other countries.
- Most new housing is in high-rise apartment buildings.

SOURCES: For urban population density, Angel et al., 2010, Table 3. For percentage of population in agglomerations of more than 1 million, World Bank, 2013. For single-family dwellings in Australia, Australian Bureau of Statistics, 2013. For single-family dwellings in Germany, Eurostat, 2014, Table "Dwelling Structure." For single-family dwellings in the United States, U.S. Census Bureau, 2011, Table C-01-AH.

### Factor Scores

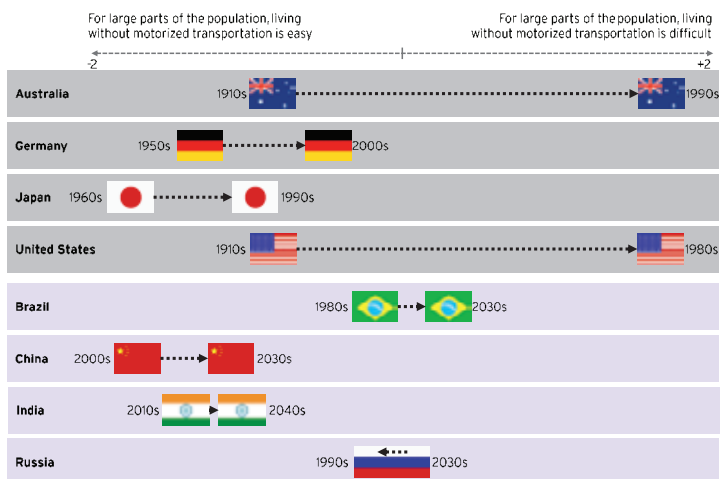


Figure C.8. Fact Sheet, Expert Observations, and Factor Scores: Spatial Dispersion

## Favorability of Car Culture

This factor describes the degree to which the overall cultural environment is conducive to automobility. This includes whether cars are important (1) to feel independent and individual (autonomy by automobility), (2) for personal space and privacy (privacy by automobility), (3) to express certain attitudes and beliefs (automobility as personal expression), (4) as a social norm, (5) as a hobby, (6) personal living space, and (7) in popular culture.

### Fact Sheet and Expert Observations

It is difficult to support this factor, which is qualitative in nature, using quantitative methods. For this reason, we relied exclusively on expert judgment. Favorability of car culture was assessed in a separate flag scoring exercise in which experts scored the factors 1 through 7 separately. The fact sheet at hand reports the most-significant findings from that assessment of the dimensions of car-culture favorability.

#### OECD countries

- OECD countries generally scored higher on car-culture favorability than the BRICs did and showed recent decreases in car-culture favorability (except the United States, where the study period ended in the 1980s). Specifically, “autonomy by automobility,” “automobility as a personal expression,” “cars as personal living space,” and “automobility in popular culture” were higher for the OECD countries than for the BRIC countries, with the United States leading in most cases. Some of these dimensions seem to develop over time as cars become more commonplace.

- Substantial differences exist between OECD countries with respect to “automobility as the social norm”: In the United States and Australia, the expectation that somebody who can afford a car would have one is as high as in the BRIC countries, but it is much lower in Japan and Germany.

- It is also noteworthy that cars and motoring as a leisure-time activity and hobby seem to be much less common in Japan than in the other OECD countries. However, unlike what non-Japanese experts expected, “privacy by automobility” scored high for Japan because cars play an important role of providing for privacy in dense Japanese urban environments.

#### BRIC countries

- Car-culture favorability is generally expected to increase in the next decades in Russia, India, and China to the level of Japan or Europe.

- In the BRIC countries, cars have not yet taken on a role to express certain attitudes and beliefs (“automobility as a personal expression”). Likewise, cars are not yet as important as a personal living space, specifically in China and India. Moreover, the car’s position in popular culture is generally less pronounced in the BRIC countries, again specifically in India.

- “Privacy by automobility” and “automobility as a hobby” are dimensions of car culture that differentiate the BRICs from each other. Specifically, for China, the importance of the car for providing privacy was rated low, while, for Brazil, Russia, and India, it was rated to be similar to that in Germany and Japan. On the contrary, “automobility as a hobby” has, in China and Russia, already taken on a similar position as that in Germany or Australia, while Brazil and especially India scored much lower in this dimension of car culture.

### Factor Scores

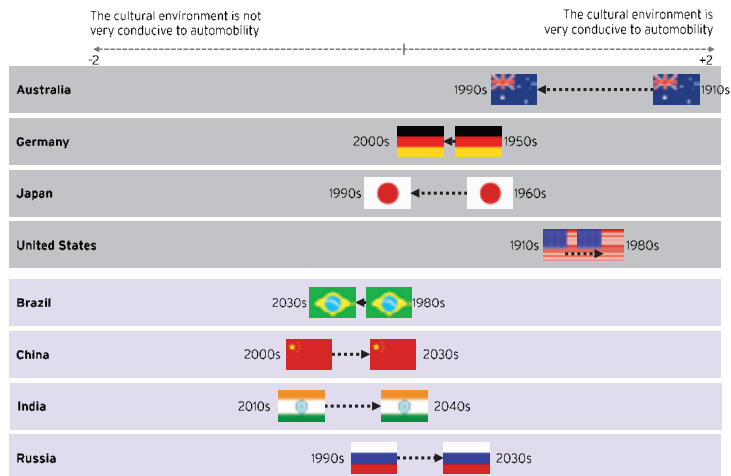


Figure C.9. Fact Sheet, Expert Observations, and Factor Scores: Favorability of Car Culture









# Appendix D

## Estimating the Parameters for a Gompertz Model of Vehicle-Kilometers Traveled Per Capita

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In this study, we used nonlinear regression to estimate a Gompertz function to explain the growth of VKT per capita over time in the four OECD countries. Although a variety of functional forms can describe the S-shaped Gompertz curve, we used the Gompertz formulation on the basis that it is somewhat more flexible than the logistic model, particularly in allowing different curvatures at low and high income levels. The model formulation is as follows:

$$y_i = Y_i \times e^{\alpha e^{(\beta_i \times \text{GDP per capita})}}$$

where

$y_i$  = VKT per capita in country  $i$

$Y_i$  = saturation level in country  $i$

$\beta_i$  = growth term in country  $i$

$\alpha$  = curvature at low levels of GDP, assumed to be generic across countries.

The VKT per capita data are annual time-series data from national sources, across various years (beginning in 1963 for Australia, 1952 for Germany, 1950 from Japan, and 1936 for the United States). For all countries, GDP per capita figures were derived from Bolt and van Zanden (2013), who have recently updated the work of Maddison (2010a). For further details on all data sources, see Appendix A.

The resulting parameters, standard errors, and 95-percent confidence intervals are summarized in Table D.1.

**Table D.1. Gompertz Model Results**

Parameter	Estimate	Standard Error	95% Confidence Interval	
			Lower Bound	Upper Bound
$\alpha$	-5.50	0.27	-6.03	-4.96
$\beta_{\text{Australia}}$	-0.178	0.006	-0.190	-0.165
$\beta_{\text{Germany}}$	-0.148	0.009	-0.166	-0.130
$\beta_{\text{Japan}}$	-0.114	0.015	-0.143	-0.086
$\beta_{\text{United States}}$	-0.134	0.005	-0.143	-0.124
$Y_{\text{Australia}}$	10,800	225	10,360	11,246
$Y_{\text{Germany}}$	9,700	542	8,633	10,768
$Y_{\text{Japan}}$	6,370	1,019	4,364	8,380
$Y_{\text{United States}}$	16,280	279	15,730	16,829



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# Abbreviations

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<b>API</b>	American Petroleum Institute
<b>BEA</b>	Bureau of Economic Analysis
<b>BITRE</b>	Australia Bureau of Infrastructure, Transport and Regional Economics
<b>BRIC</b>	Brazil, Russia, India, and China
<b>BTS</b>	Bureau of Transportation Statistics
<b>CAFE</b>	Corporate Average Fuel Economy
<b>CIA</b>	Central Intelligence Agency
<b>EIA</b>	U.S. Energy Information Administration
<b>EV</b>	electric vehicle
<b>FHWA</b>	Federal Highway Administration
<b>GDP</b>	gross domestic product
<b>GHG</b>	greenhouse gas
<b>GMMN</b>	Global Mobility Monitor Network
<b>GPS</b>	global positioning system
<b>ifmo</b>	Institute for Mobility Research
<b>IRF</b>	International Road Federation
<b>ITRD</b>	International Transport Research Documentation
<b>JAMA</b>	Japan Automobile Manufacturers Association
<b>KBA</b>	Kraftfahrt-Bundesamt
<b>OECD</b>	Organisation for Economic Co-Operation and Development
<b>PPP</b>	purchasing power parity
<b>TRB</b>	Transportation Research Board
<b>TRID</b>	Transport Research International Documentation
<b>TRIS</b>	Transportation Research Information Services
<b>ViZ</b>	Verkehr in Zahlen
<b>VKT</b>	vehicle-kilometers traveled
<b>VMT</b>	vehicle-miles traveled









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RR-636-ifmo

ISBN-10 0-8330-8604-9  
ISBN-13 978-0-8330-8604-4



**\$59.95**

