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Institute for Mobility Research

THE FUTURE OF DRIVING IN THE BRICS COUNTRIES. (STUDY UPDATE 2019)

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Contents

Imprint

Applying basic relationships in context of car usage and ownership found for industrialized countries, the present report predicts future car usage and motorization levels for the BRICS countries. This report is an update of the 2014 study "The future of driving in developing countries".

The research was sponsored by the Institute for Mobility Research (ifmo) and conducted under the lead of the DLR Institute of Transport Research, Berlin.

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Foreword

The ownership and use of private cars continues to rise worldwide, as higher standards of living are achieved in many parts of the world. The coupled growth of car ownership and car use with economic growth presents a significant challenge, particularly with regard to mitigating climate impacts. Predictions by the International Energy Agency assume a more than doubling of the global passenger transport between 2015 and 2050. If private cars continue to rely on fossil fuels, such growth would further stress the global climate system. If they were to use electricity or other energy carrier, steps to establish a sufficient and sustainable infrastructure would be required as early as possible.

Knowledge about the level of motorization and use of cars is of great importance to evaluate the potential impacts, and to plan and design appropriate solutions to minimize negative effects. Knowing where such growth occurs allows for better policy design and appropriate planning instruments. Anticipating the level of growth enables governments to pro-actively create alternatives that can satisfy the increased demand. The motorization rates are also key drivers to evaluate, plan and develop alternative technologies to the internal combustion engine.

In 2014, the first study on the future of driving in the BRIC countries established a new approach to predict the level of motorization and driving in Brazil, Russia, India and China. Until then, most predictions on motorization and the use of individual vehicles were based on the growth of wealth in countries. While the general trend holds true that rising income is related to grow in motorization and vehicle kilometers travelled, large differences exist between countries and cannot be explained by income, in terms of gross domestic product per capita, alone. Hence, other explaining aspects were integrated by qualitatively analyzing country differences along nine thematic factors.

Since then, new statistical figures have become available and countries have regained economic momentum after the down-turn of 2008/09. A study update after five years is warranted, to integrate those new data and insights into the analysis. Furthermore, with the study update South Africa was added to the list of countries and thus the approach now covers all continents. The study update thus contributes to better understand the dynamics and reasons for the motorization and use of cars in BRICS countries.

Since 2014, also new trends have emerged that call for increasing attention: new mobility services based on digitization and automation offer shifts in the way we organize the transport system. Furthermore, since the Paris Agreement, the question of future propulsion technologies for mobility has gained momentum. Therefore, the study has also expanded in those two areas by assessing potential development pathways in the BRICS countries.

The study update "The future of driving in BRICS countries" continues to think through the development of individual mobility, by looking beyond purely statistical figures. This makes it a valuable contribution for politicians, planners, and stakeholders of the mobility industry.

Prof. Dr. rer. nat. Barbara Lenz
Director, DLR Institute of Transport Research
Member of the ifmo Board of Trustees

Executive Summary

This study is an update of one previously published a few years ago. The aim of the original study, The Future of Driving in Developing Countries (Ecola et al. 2014), and also of this update, is to investigate the factors that will influence the future path of automobility in emerging economies. Generally speaking, as wealth – expressed as GDP (gross domestic product) per capita – increases, both the number of vehicles per 1,000 population (motorisation) and total vehicle-kilometres travelled (VKT) rise. The way that motorisation and VKT have risen in countries that have reached high levels of income in every case follows an S-shaped curve, as wealth has increased, with these two indicators levelling off as average wealth enters the region around 35,000 to 40,000 US$2011 GDP per capita. However, the saturation level in each country differs. It follows that factors other than GDP influence, and may well explain, a country's saturation levels of motorisation and VKT.

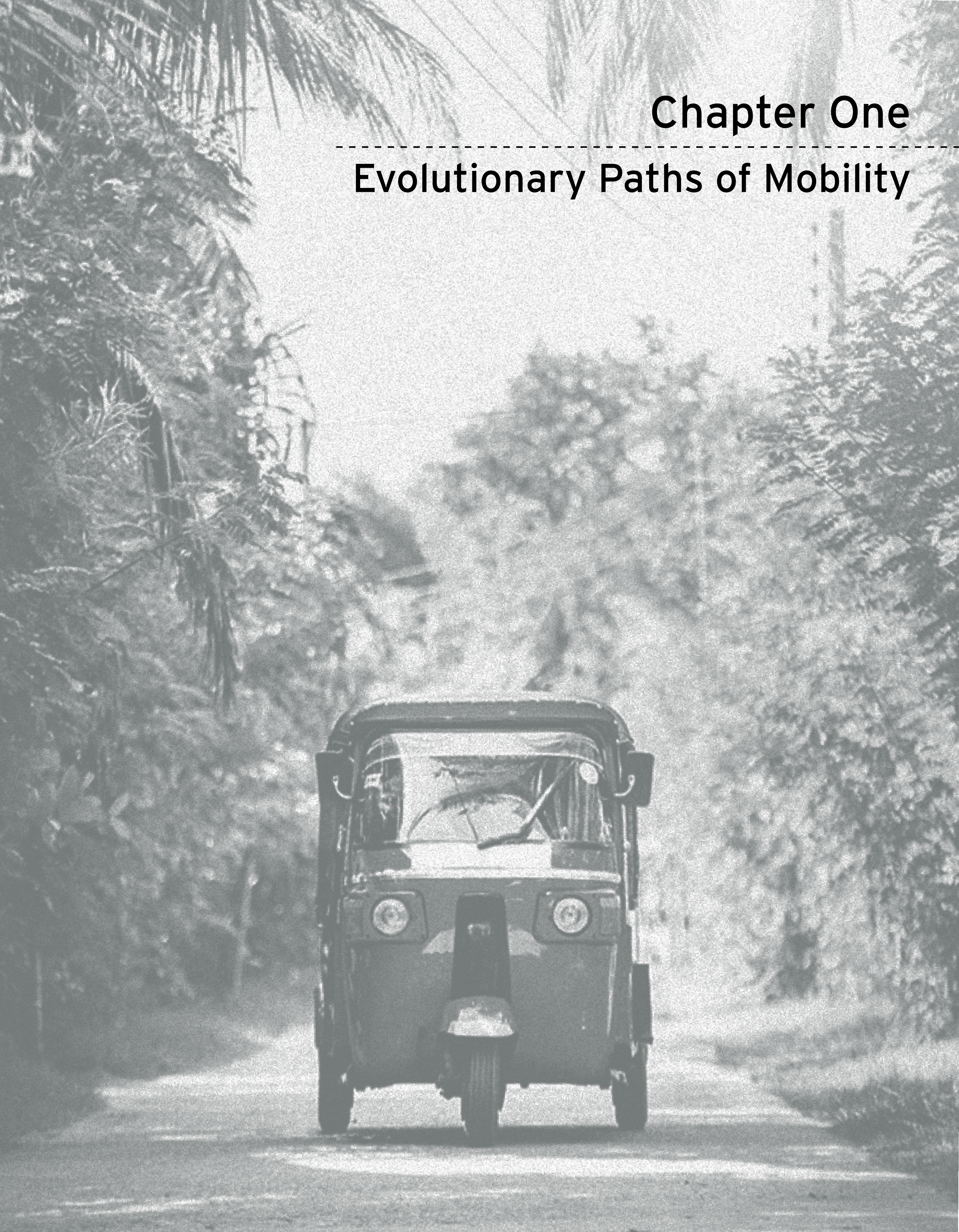
In this project we identified factors other than GDP which have a strong influence on automobility. Nine factors were selected that sufficiently explain the differences of saturation levels seen in the various countries in the Organisation for Economic Co-Operation and Development (OECD). By assessing the expected role of those factors in the emerging economies (for our study, the BRICS countries: Brazil, Russia, India, China, South Africa), we can extrapolate expected saturation curves for them. Since the BRICS countries have not yet reached levels of wealth where saturation can be expected, the approach relies on projections into the future of the development of these factors in each country. To formulate these projections, we combined statistical data and trends analysis with qualitative expert judgement. Sixteen country experts gathered together in a two-day workshop to create projections of the factor developments in the BRICS countries.

The results show a great variance between the BRICS countries, explicable by structural differences. The spatial settings – and, in conjunction with them, the possible alternatives to private automobility – play an important role. Furthermore, policy interventions may have a great influence on motorisation rates and VKT. Additionally, since saturation levels are tied to the attaining of levels of individual wealth, the time horizon when those saturation levels may be reached also differs strongly between countries. Our projections for VKT saturation levels range between 5,700 VKT per capita for India and 12,700 VKT per capita for South Africa, reached in the 2060s and 2050s respectively. The most populous country, China, is projected to saturate at between 6,000 and 6,700 VKT, in the 2030s. Translating those VKT numbers into saturation levels for motorisation results in cars per 1,000 population figures ranging from 290 (India) to 730 (South Africa).

In addition to VKT saturation projections, we investigated the appearance of new mobility services and the emergence of new propulsion systems. New mobility services are expected to achieve a modal share of between 7% (Australia) and 27% (United States) by 2050. In the BRICS countries, new services may reach shares of 22% in Brazil, 17% in China, 15% in Russia, 11% in India and 10% in South Africa. According to expert judgement, only in Australia, Japan, China, India and Russia will the new mobility services make most of their gains from displacing private cars. In the other countries, such services are expected to diminish non-car modes more strongly. With regard to propulsion systems, pure battery electric vehicles are expected to attain a share of more than 50% by 2050 in Germany, Japan and China. Smaller shares are projected for Australia, India and Russia, with levels of between 20 and 30%. In Brazil, biofuels take some of the modal share, and only in South Africa, Russia and India will the diesel engine remain, taking a 5–25% share. In Germany, the United States and India, the application of hydrogen as a fuel is also expected to emerge.

Chapter One

Evolutionary Paths of Mobility



1.1 Study Objectives

In 2014, ifmo and The Rand Corporation published a report titled The Future of Driving in Developing Countries (Ecola et al. 2014). The purpose of the report was to compare and contrast the evolution of mobility in developing countries with that of countries that had, by the twentieth century, already developed.

A few years later, this report takes up the same thread again, with the aim of updating the results and adding new perspectives. The essential concepts and considerations of the earlier work are adopted, in particular the assumption of an 'evolutionary path' of development of mobility, the notion of a 'saturation level' with respect to VKT, and the concept of a 'motorisation period' defined as period during which a motor vehicle becomes a commonly owned consumer good for large segments of a country's population.

The central research questions are:

- What factors affect automobility and how will they develop in the future?
- How and to what extent do these factors influence automobility?
- Do these factors influence automobility in emerging countries in the same way as they once did in today's developed countries?

Taking into account current changes in the mobility market and vehicle development, two further areas were identified that are likely to have a considerable influence on future automobility: the dynamic emergence of new mobility services and a shift towards innovative propulsion technologies. While the former holds the promise of enabling consumers to make better use of transport modes, the latter aims to cope with foreseeable shortages of fossil-fuel energy sources and to reduce harmful emissions.

Notwithstanding these refinements, the reason behind the overall approach adopted for forecasting the future development of automobility in different countries was to ensure the greatest possible comparability with the preceding study.

The selection of the countries to be investigated remained largely unchanged, with only South Africa being added as an emerging and developing economy in the African continent. The following report represents a synthesis of research and findings from the DLR Institute of Transport Research, as well as of findings from a two-day workshop hosting 16 transport experts from the nine study countries.

1.2 What Influences Mobility?

Global demographic and economic developments are probably the main drivers of mobility worldwide. In general, the mobility of people rises as the countries in question are more actively engaged in the global economy, and as levels of individual wealth increase. Current models for predicting the global demand for transport take population and economic development as the major external factors that influence mobility, as well as future motorisation rates (Yeh et al. 2017). However, mobility cannot be considered one and the same as the ownership and use of a private car, as mobility needs might also be met by public modes of transport, and, increasingly, by two- and three-wheelers.

Within this report, we will differentiate between mobility, defined as the overall demand for individual passenger mobility, regardless of the transport mode; and automobility, defined as the degree of individual mobility using some sort of individual passenger car, whether owned, leased or shared. While the focus is on the development of passenger cars, the projected mobility demand may in some cases be satisfied with 2- and 3-wheeled vehicles. In addition, we identify motorisation as the rate of personal ownership of vehicles (Ecola et al. 2014), expressed in vehicles per 1,000 population.

Despite the fact that population and economic development are the main drivers of automobility, research has also shown that the development of motorisation and car use cannot be explained solely by those factors (BITRE 2012b; Dargay et al. 2007). Yeh et al. (2017) also point to the large uncertainty of projections of motorisation and car use, where the role of urban areas, income distribution and infrastructure conditions in particular are poorly represented in existing models. This train of thought was also the motivator for the first study, (Ecola et al. 2014). The development of automobility in the four OECD study countries showed a great diversity, although it remained in general correlated to economic growth and wealth (Figures 1.1 and 1.2).

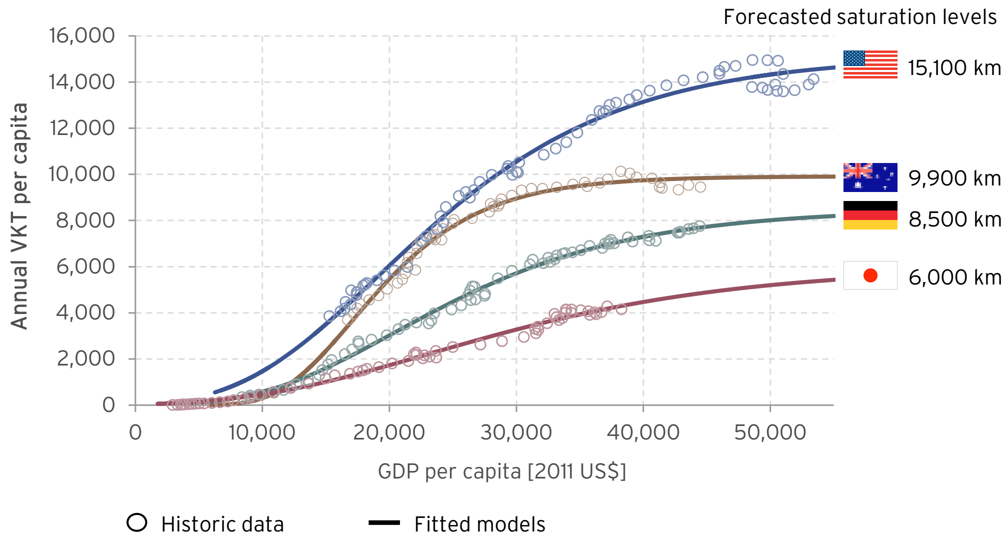


Figure 1.1. Vehicle-Kilometres Travelled Plotted Against GDP Per Capita PPP

*SOURCES: **GDP (all countries)**: 1900–1989: Bolt et al. (2018a). 1990–2017: World Bank (2019). 2018–2050: IIASA (2016). **Population Australia, Japan, United States**: until 2016: Bolt et al. (2018a). 2017–2050: IIASA (2016). **Population Germany**: until 1992: DESTATIS (2016). 1993–2016: Bolt et al. (2018a). 2017–2050: IIASA (2016). **Vehicle-kilometres Australia**: 1963–2010: BITRE (2012b). 2012–2016: ABS (2017). **Vehicle-kilometres Germany**: BMVI (2017). **Vehicle-kilometres Japan**: until 2004, 2009: Statistics Japan (2012a). 2005–2008: Statistics Japan (2011a). 2011: MLIT (2014). 2013: MLIT (2015). 2016: MLIT (2018). **Vehicle-km United States:** 1950–1995: U.S. DOT – FHWA (1997b). 1996–2016: U.S. DOT – BTS (2018a).*

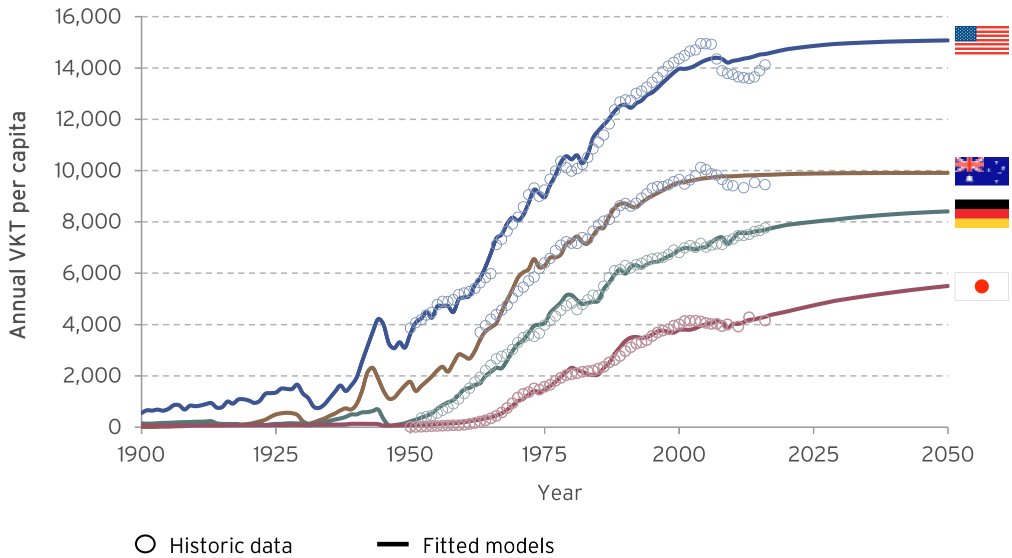


Figure 1.2. Vehicle-Kilometres Travelled Plotted Over Time

*SOURCES: **Population Australia, Japan, United States:** until 2016: Bolt et al. (2018a). 2017–2050: IIASA (2016). **Population Germany**: until 1992: DESTATIS (2016). 1993–2016: Bolt et al. (2018a). 2017–2050: IIASA (2016). **Vehicle-km Australia**: 1963–2010: BITRE (2012b). 2012–2016: ABS (2017). **Vehicle-km Germany**: BMVI (2017). **Vehicle-km Japan**: until 2004, 2009: Statistics Japan (2012a). 2005–2008: Statistics Japan (2011a). 2011: MLIT (2014). 2013: MLIT (2015). 2016: MLIT (2018). **Vehicle-km United States**: 1950–1995: U.S. DOT – FHWA (1997b). 1996–2016: U.S. DOT – BTS (2018a).*

When comparing results with the former study, several trends can be observed:

- In the United States, the VKT dipped after the economic crisis of 2008 but started to increase again in 2014.
- In Australia, the VKT declined between 2007 and 2010, and levelled off thereafter.
- Germany's VKT saw a steady growth, picking up pace from 2000. The saturation level may not even have been reached as yet.
- Japan's growth in VKT peaked in 2002, but started to rise slightly again from 2011. The visual impression is that saturation levels probably have been reached, despite the fact that the model predicts a further rise, owing to the strong increase between 1990 and 2002.

What has not changed is the large difference seen in VKT between the four developed countries. We can thus conclude that the development of VKT cannot be explained by economic development alone. **To further investigate the factors that influence VKT was the focus of the former study, and it is the focus of this update.** We will also look into developments of motorisation, although the relationship between motorisation and GDP per capita is weaker that that connecting VKT and per-capita GDP (see section 3.2, 'Derivation of saturation levels for the BRICS countries').

1.3 The Study Methodology

In order to ensure the greatest possible comparability with the preceding study, the same overall approach was adopted, but it was then selectively extended (Figure 1.3).

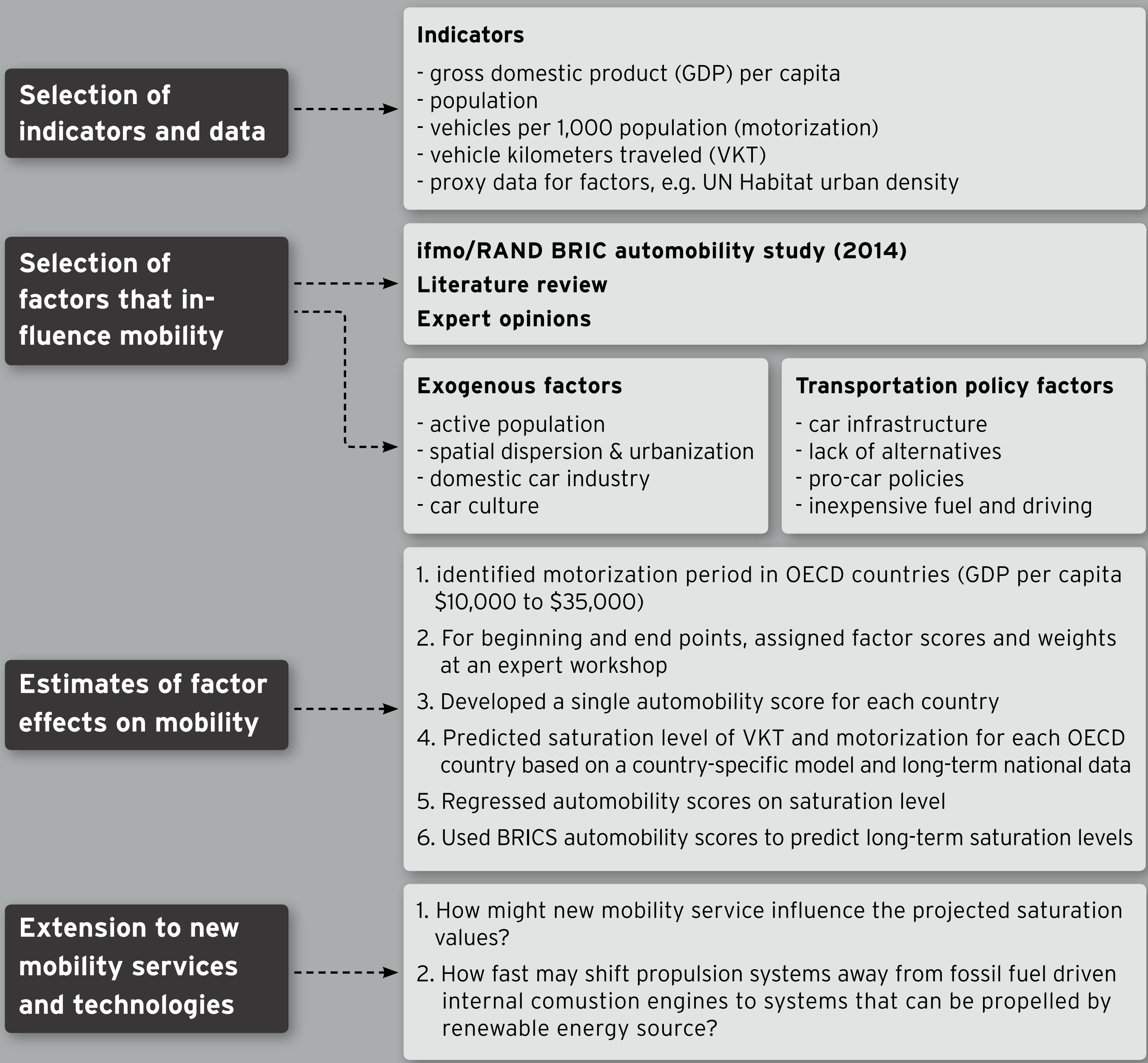


Figure 1.3. Methodological Approach

1.3.1 Selection of indicators and data sources

The comparison of the development paths of the individual countries is based on a set of data sources that differ from one country to another. It was already clear in the previous project (Ecola et al. 2014: 15) that there were no perfect data for the selected indicators. Availability of time series, as well as quality and comparability, differ considerably between the countries.

As the primary task was to pursue the development paths identified in the previous project, in most cases the same data sources were used as our starting point. Whenever possible, data were updated to 2016 or 2017; more recent data were for the most part not yet available.

During work on the previous project it already became clear that it was not always possible to find suitable common statistics that include all the study countries. This was particularly the case for vehicle stock and travel data, as national statistics do not define the difference between passenger cars and light commercial vehicles in a consistent way. Moreover, the time series of an individual country are also subject to occasional changes, sometimes resulting in discontinuities.

For each country, the following items of data were collected in order to assess its overall situation, and to define its indicators:

- GDP per capita;
- population;
- motorisation;
- VKT; and
- additional proxy data for factor fact sheets.

Both GDP per capita and VKT were retained as central indicators – GDP per capita to determine the economic development of a country and VKT as a measure of mobility.

- **GDP per capita** was used as an indicator of a country's economic development. For the period 1990 to 2017 the data from the World Bank's World Development Indicators (WDI) (World Bank 2019) in 2011 international US$ in purchasing power parity (US$2011 PPP) was used. PPP "converts different currencies to a common currency and, in the process of conversion, equalise their purchasing power by eliminating the differences in price levels between countries" (OECD & Eurostat 2012: 13). For the period up to 1990, the time-series data from the Maddison Project provided the factors for deriving the historic GDP per capita figures (Bolt et al. 2014, 2018a, 2018b). For the outlook forecasting the future development of GDP per capita, we used a dataset by the International Institute for Applied Systems Analysis (IIASA2016) that describes GDP growth rates in the context of scenario analysis for the Intergovernmental Panel on Climate Change, the so-called 'Shared Socioeconomic Pathways' (SSP). We selected the GDP dataset for a 'business as usual' development (SSP2), which was generated by applying an economic model from the OECD. In contrast to the former project, the choice of data implies a change in the currency unit used. While Ecola et al. (2014) projected GDP per capita with the Geary-Khamis $1990, the World Bank data are in US$2011. This results in higher absolute values than those in the former project.

- **Population** data followed a similar approach. While the values for the core years 1990 to 2017 stem from the World Bank's WDI database, factors for deriving historic and future figures were generated using the Maddison Project and the IIASA SSP2 data respectively.
- **Vehicle stock and vehicle-kilometres travelled** were taken from national statistics of the OECD countries. Data were processed by the DLR Institute of Transport Research to generate consistent time series, for example merging the German datasets prior to 1990 from both East and West Germany. No reliable figures for the BRICS countries are available.
- **Data for factor fact sheets** were derived from multiple sources of international organisations and industry associations. For example information on car production in countries was taken from the International Organization of Motor Vehicle Manufacturers (OICA 2017). The sources are shown in the corresponding figures.

1.3.2 Selection of factors that influence mobility

In seeking to understand the influences on mobility for the report The Future of Driving in Developing Countries, Ecola et al. (2014: 13ff.) identified nine factors that characterise the future path of automobility development. Since these factors had proven to be suitable for answering the research questions, all of them except for the factor 'existence of domestic oil', were retained, with minor changes in the elaboration where appropriate.

The result is a final list of eight factors that provide indication primarily on motorisation and VKT (Table 1.1).

Table 1.1. List of Factors Influencing Mobility, Adapted from Ecola et al. (2014: 23)

Faktor	Description
Active population	The share of the population at a stage in life that is characterised by high mobility rates; this includes both demographic effects (i.e. age groupings in which mobility is typically high) and workforce participation (i.e. the share of the working-age population who are employed)
Spatial dispersion	The extent to which settlement patterns are conducive to automobility; this includes (1) the share of people living in urban agglomerations and (2) the population density of urban built-up areas
Domestic car industry	The existence of a domestic car industry, and its relevance to the national economy and politics
Car infrastructure	All infrastructure for driving, taking into account both the quality and the quantity of roads, parking, and level of service
Lack of alternatives	How car-focused the transport supply in a country is vis-à-vis the infrastructure in place for alternative modes of urban and interurban travel
Pro-car policies	All non-infrastructure policies and legislation concerning motorisation and usage of cars, including vehicle costs (e.g. registration fees), regulations (e.g. driving restrictions), and specific policies (e.g. Germany's 'cash for clunkers' scrappage scheme)
Inexpensive driving	Whether the price of driving (including taxes) is inexpensive relative to income
Car culture	Affinity to cars from a cultural perspective

The factor car culture is probably the one which is most difficult to capture by means of statistics. For this reason, we have conducted an online survey of experts from the study countries.[1] On a scale of 1 to 5, experts were asked to judge whether aspects of car culture are irrelevant or highly relevant in the study countries. The assessment was made comparatively with regard to seven dimensions:

- Autonomy: do cars foster individuality and independency?
- Privacy: does perceived privacy and comfort promotes the use of cars?
- Status symbol: are cars an expression of economic wealth and status?
- Personal living space: are cars a place for carrying out day-to-day activities?
- Expression of personal attitudes: do cars express the beliefs of the owners?
- Automobility as a hobby: do cars and automobility constitute a hobby?
- Automobility in popular culture: do cars appear centre stage in popular culture?

The factor 'existence of domestic oil' was separated and complemented by four further factors, all of them dealing with different aspects of energy supply and use. In addition to the availability of domestic oil, those are the availability of domestic gas ('domestic gas'), the carbon intensity of electricity supply ('national electricity supply'), subsidies on diesel fuel ('diesel fuel'), and the share of non-fossil propulsion systems ('electrification of mobility') (see Table 1.3 and Chapter Four, The Future Role of New Mobility Services and Technologies). The issue of the increasing availability and use of new mobility services was also discussed separately from the previous factors (see Chapter Three, Future Mobility Paths of the BRICS Countries).

[1] In total 59 experts responded, of whom 40 were transport researchers, nine engineers, six educational experts, three consultants and one an economic professional. The highest numbers of respondents were from South Africa and Russia, followed by Japan, India, Brazil and Germany. From Australia, the United States and China, only a small number of experts responded.

1.3.3 Estimates of factor effects on mobility

When analysing the motorisation rates in countries, a general correlation between personal wealth and motorisation can be observed. Nearly all countries display an S-shaped curve in the development of motorisation, in terms of both motorisation and VKT. In the former report, as well as in other studies, the development of motorisation was plotted against the development of the countries' GDP. A period of rapid growth of motorisation leading to a saturation level can be observed (Figure 1.2).

In line with the methodology of the former study, the development of vehicle ownership and vehicle use (expressed as VKT) was analysed for the four OECD countries (Australia, Germany, Japan and the United States). When using 2011 international US$ as a basis, the period of most dynamic motorisation is seen to lie somewhere between 10,000 and 35,000 US$2011. However, the approximation of saturation levels in each country differ significantly, as do growth rates of motorisation. Furthermore, saturation levels of vehicle ownership and VKT point to different influences. Japan in particular shows higher vehicle ownership rates than Germany, but at the same time lower VKT levels.

Generally, the relationship between VKT and GDP per capita is more pronounced than the connection between motorisation and GDP per capita. This indicates a stronger correlation between VKT and economic development than between motorisation and economic wealth. The saturation levels of VKT have been calculated using a Gompertz function, a model to describe the S-shaped relationship. The calculation of saturation levels for motorisation therefore follows a different approach from the previous study (see Chapter Three, Future Mobility Paths of the BRICS Countries). Furthermore, the Gompertz function depends strongly on the input data and uses lagged dependent variables to improve reliability. The use of historic GDP per capita figures, in particular, introduces a measure of uncertainty. The early development of GDP and VKT has, however, an influence on the shape and the saturation levels fitted with the Gompertz function. The former study used figures for the period 1900 to 2010/2011; we have updated those figures to 2016/2017. The saturation levels in this update of Ecola et al. (2014) differ from prior levels owing to the update of real figures for GDP per capita to 2017, and, related to this, slightly different historic GDP per capita figures (Table 1.2). In particular, the recession years 2009–2010 gave rise to non-uniform developments in VKT per capita (Figure 1.2), with the increase in VKT during those years being dampened. Generally, these kinds of fluctuations and the resulting uncertainty in the analysis mean that some care is advisable when interpreting the results. We have therefore rounded the saturation levels to the nearest 100 VKT.

Table 1.2. Updated Saturation Level of Vehicle-Kilometres Travelled

Country	Saturation level of VKT (Ecola et al. 2014)	Saturation level of VKT (Update)
Australia	10,800 km	9,900 km
Germany	9,700 km	8,500 km
Japan	6,400 km	6,000 km
United States	16,300 km	15,100 km

Statistical data alone often tell only part of the story. In view of this, the personal consultation of transport experts from all study countries during a two-day workshop formed an equally important part of the analytical process. The decision to conduct such an expert workshop results from an understanding that restricting analysis purely to statistical figures is not sufficient for fulfilling the assessment task needed to forecast future automobility in emerging countries. First, the statistical data for those countries are incomplete, and sometimes of questionable quality. Second, even when reliable statistical data exist, because of the heterogeneity of the individual countries, comparisons based solely on such data and the conclusions drawn from them remain problematic. As an example, although population density data are available for the vast majority of countries, they alone are not sufficient to characterise the spatial structure of a country. While in some countries (e.g. Australia and China) the dynamic regions are concentrated in a small fraction of the country, in others (e.g. Germany and India) they are scattered across the country.

Most of the study countries were represented by two experts from different institutions, except in the cases of Australia, Japan and the United States, where one expert was present for each country. Fortunately, nine out of sixteen experts[2] had already participated in the initial workshop five years ago and were therefore quite familiar with the objectives and methodology[3] of the workshop.

[2] See Appendix B for a list of experts and their affiliations.

[3] The workshop followed the Chatham House Rules (https://www.chathamhouse.org/chatham-house-rule#). Furthermore, the consensus principle was followed. Therefore statements made by experts during the workshop are integrated into the text, without reference.

During the workshop, an intense discussion among experts and members of the project team took place. Following some general information about the workshop format and the expected contribution by participants, the discussion was stimulated by condensed information about each factor. For each factor a fact sheet provided basic quantitative and qualitative information for the study countries, along with a brief statement outlining both its current state and its expected development in each country. Using their professional expertise, as well as their in-depth knowledge of the local conditions and current trends in their countries, the experts were able to assess the statistical information provided and gave further valuable insights. For each factor they were asked to reconsider the statements made in the former project's workshop on the development of their country and, if necessary, to adjust them.

The expected outcome of these expert assessments were **factor scores** indicating the relevance of each factor in terms of either favouring or impeding the trend towards automobility. The factor scores were determined by means of a so-called 'flag game', where participants moved the flags of each country taking into account the position of the other countries, in particular in comparison to the four OECD countries that are approaching saturation levels of motorisation (Figure 1.4). As in the previous study, the initial flag positions of each country reflect the situation at the onset of increasing motorisation on the one hand (corresponding to a per-capita GDP of approximately 10,000 US$2011) and on the other hand of flattening of motorisation, reaching towards saturation level (corresponding to a per-capita GDP of approximately 35,000 US$2011). While the factor scores in the case of Australia, Germany, Japan, and the United States refer to periods in the past (i.e. the respective motorisation periods of each country), the values for the BRICS countries anticipate the future development of motorisation.

The final flag positions, as agreed upon during the workshop, were subsequently assigned a numeric score on a scale of values ranging from -2 to +2, representing the possible extremes of manifestation of each factor (e.g. -2 correlates with 'hindering' and +2 with 'encouraging' automobility in a country) (Figure 1.4 shows an example; the complete set for all factors is in Appendix A).

[4] The fact sheets on the various factors were made available to the experts prior to the workshop.

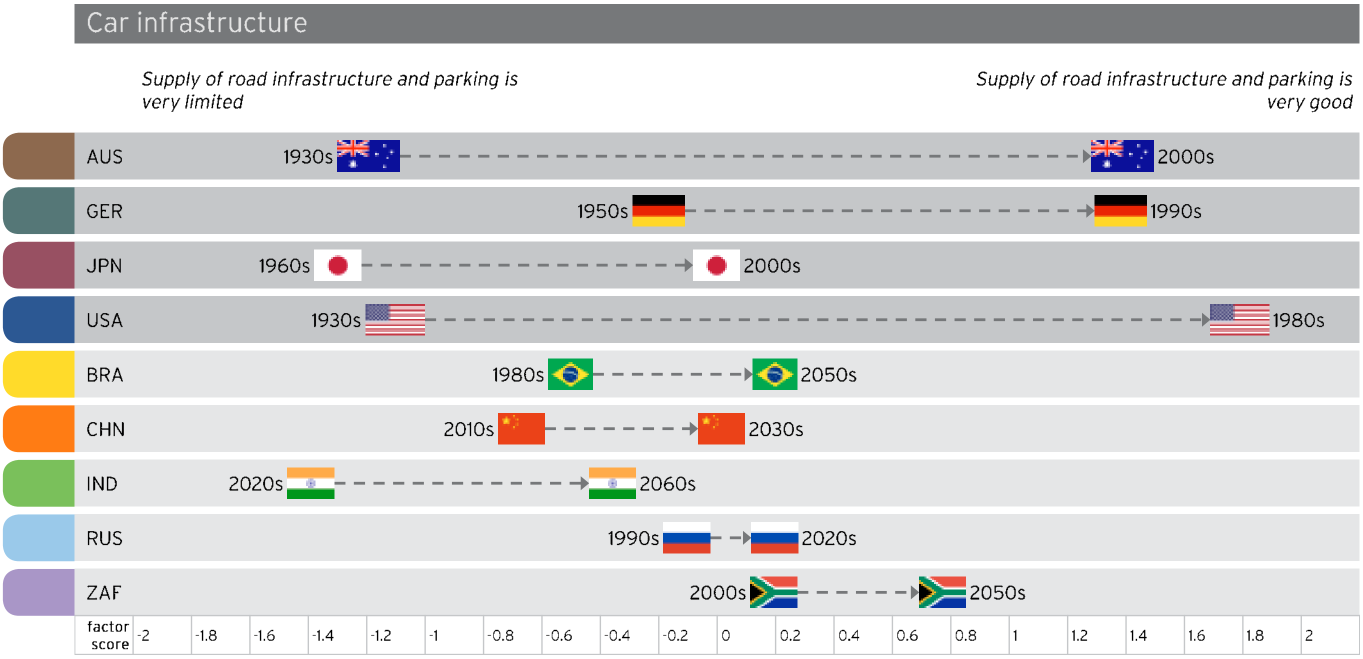


Figure 1.4. Example of the Flag Game Assessment for the Factor Car Infrastructure

NOTE: AUS = Australia, GER = Germany, JPN = Japan, USA = United States of America, BRA = Brazil, CHN = China, IND = India, RUS = Russia and ZAF = South Africa, according to ISO 3166 alpha-3-codes.

A second step of the assessment procedure was the determination of overall **factor weights** describing the significance of an individual factor for the future development of automobility, expressed in terms of as VKT and motorisation. Factor weights ranged from 1 to 3, where 3 represents the greatest impact. The assumption behind this scoring is the that different factors have different influences on automobility. Furthermore, while some factors may foster the ownership of cars, others may tend more to encourage their use.

In the previous study a distinction was made between exogenous factors and transport policy factors. In the words of Ecola et al. (2014: 22): "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." In this study update we did not focus on that distinction, but we will come back to it when comparing the results of this update with the results from Ecola et al. (2014) (Chapter Three Future Mobility Paths of the BRICS Countries).

Finally, both factor scores and factor weights were combined into an automobility score (AS) that describes how favourable the conditions in a country are for automobility. Similarly to the former study, we created weighted sums for each factor for both time periods – the beginning of the motorisation phase and the reaching of saturation points, using the factor weights. The final automobility score is then the average of all weighted factor scores. The higher the **automobility score**, the more likely is a high level of vehicle ownership and VKT.

In the aftermath of the workshop, the experts had the opportunity to make further comments, to reconsider their statements and, if necessary, to complement or revise them.

1.3.4 Extension to new mobility services and technologies

Some noteworthy trends have emerged since the first study was conducted in 2014. Two discussions in particular are dominating the discourse on automobile development.

The first is the appearance of new mobility services, such as car-sharing and ride-hailing services. This trend has built on experiences with car sharing that go back to the 1980s. However, new technologies, digitalisation and the prospect of automation offer fresh opportunities for new mobility services to eventually meet a significant proportion of peoples' mobility needs in years to come.

The second is the rapid development of new propulsion technologies, mainly the shift away from fossil fuel driven internal combustion engines to systems that can be propelled by renewable energy sources. As with new mobility services, early developments of electric vehicles and hydrogen-powered ones also date back to the 1970s and 1980s, with electric drivetrains even being experimented with in the early years of the automobile. However, progress in the generation of renewable power and the prospect of shifting from foreign power sources to domestically produced electricity has spurred such development in recent years.

These two phenomena have been captured as separate indicators, and additional indicators were also identified (Table 1.3).

Table 1.3. Additional factors Influencing Car Use and Fleet Composition

Factors	Description
New mobility services	Appearance of new mobility services
Domestic oil	Availability of domestic oil resources
Domestic gas	Availability of domestic gas resources
Diesel fuel	Degree of diesel fuel subsidies
National electricity supply	Carbon intensity of domestic electricity supply
Electrification of mobility	Degree of vehicle electrification

1.4 Insecurities

Gathering and comparing data from different countries and different sources is always a challenge, and one that requires particular attention when it comes to analysing them. While long time series are generally available for the majority of factors in the OECD countries, the situation in the BRICS countries is quite different.

Some of these countries have experienced enormous political upheavals, economic transformations and societal changes, which may also have influenced the focus of official statistics, for instance data on national economic development such as GDP. One must always be aware that data may show a certain bias, since they are widely used for political purposes and policy development. Moreover, data from private sources, such as business associations, may also be biased in a similar way, albeit for other reasons.

Apart from the implicit purpose behind each data source, another problem lies in the complexity of phenomena to be represented. Each country and each discipline has its distinctive particularities and traditions, leading to different definitions and classification schemes. This became particularly evident in the context of vehicle statistics.

Further uncertainties arise from the explicit consideration of qualitative assessments by external experts, who are characterised by their professional backgrounds, in-depth knowledge of local specifics, and insider knowledge. However, this subjectivity is expressly desired, since it serves to provide further assessment and interpretation of the bare statistics.

1.5 Report Organisation

Apart from this introduction, this report contains five further chapters. Chapter Two provides background information on each factor presumed to affect the level of mobility. Findings are based on a broad set of statistical indicators for each country. The starting point was the large amount of data that had already been collected for the preceding project. Depending on their availability, data have been updated by five to six years. Chapter Three presents the most important analytical results for the five emerging countries, based on desk research and intensive discussion with proven experts from their respective countries. Chapter Four is devoted to exploring the role that new mobility services and technologies will play in the further development of mobility. Chapter Five summarises the main conclusions drawn from this study. Two appendices supplement the report: Appendix A provides the results of the expert observations and factor scores, in the form of diagrammatic results of the flag game, while Appendix B lists the country experts consulted during the project.

Chapter Two

Factor Findings for the Study Countries

2.1 Active Population

"Active population refers to the share of the population in a life stage characterised 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" (Ecola et al. 2014: 46). We chose the share of the population aged between 15 and 64 (Figure 2.1) and the share of female labour participation as indicators for the proportion of the population in the active workforce (Figure 2.2). With regard to the population of age 15–64, we also included a projection for 2010 onwards made by IIASA (Riahi et al. 2017), in order to visualise the trends in the countries. The official figures for employment were not considered, because they do not cover informal work and societal participation, which can be significant in some countries. Thus the above-mentioned datasets represent the most relevant data for indicating the share of population with high mobility rates.

Demographic science differentiates four stages at which a country can find itself, with regard to its economic prospects related to demographic development: pre-dividend countries, early-dividend countries, late-dividend countries and post-dividend countries. This typology identifies two phases of potential economic dividends to society: the first dividend (the early dividend) becomes possible when a growing workforce supports fewer children. The second dividend (the late dividend) may or may not be possible, and occurs if the wealth of the first dividend phase can be directed into human and physical capital, and productivity can thereby increase (World Bank Group 2016). While the four OECD study countries (Australia, Germany, Japan, and the United States) belong to the post-dividend countries, the demographic development stage of the BRICS countries is more heterogeneous. Brazil, China and Russia belong to the late-dividend countries, whereas India and South Africa fall into the category of early-dividend countries. However, whether demographic structures foster or hamper prosperity, and thus motorisation and car use, depends on the achievements made in the respective phases of demographic characterisation. Early-dividend countries are still in a population growth phase, with an increasing active population, and are thus in a position to build on their human capital. Late-dividend countries face a shrinking active population, and have the opportunity to build and secure economic strength through investing their savings to increase the productivity of labour. A hampering of prosperity occurs if a late-dividend country does not manage to secure workforce productivity and wealth savings acquired during earlier periods.

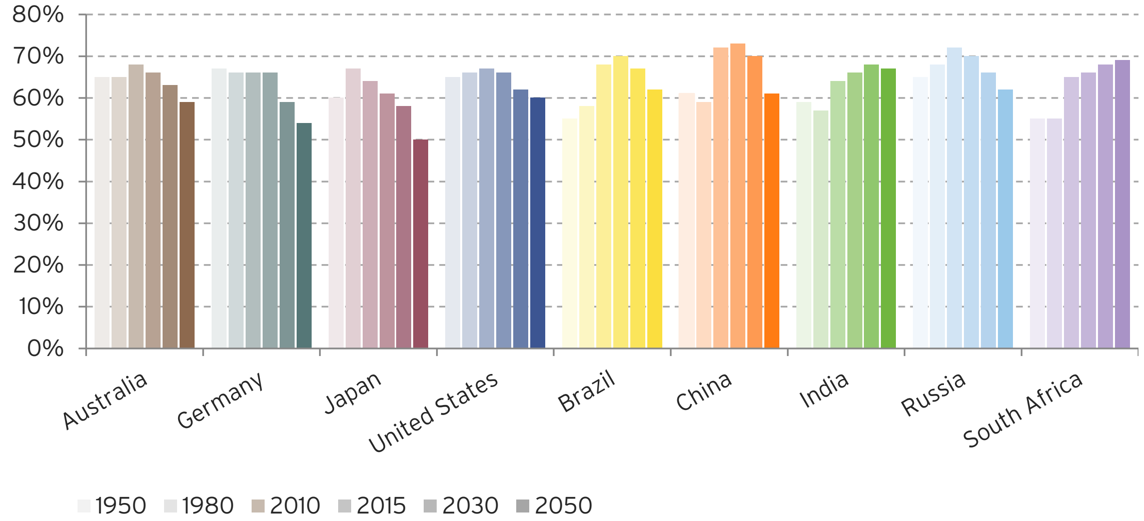


Figure 2.1. Working Age (15–64) Population as Percentage of Total Population

SOURCE: 1950, 1980: OECD (2018); 2010 onwards: Riahi et al. (2017).

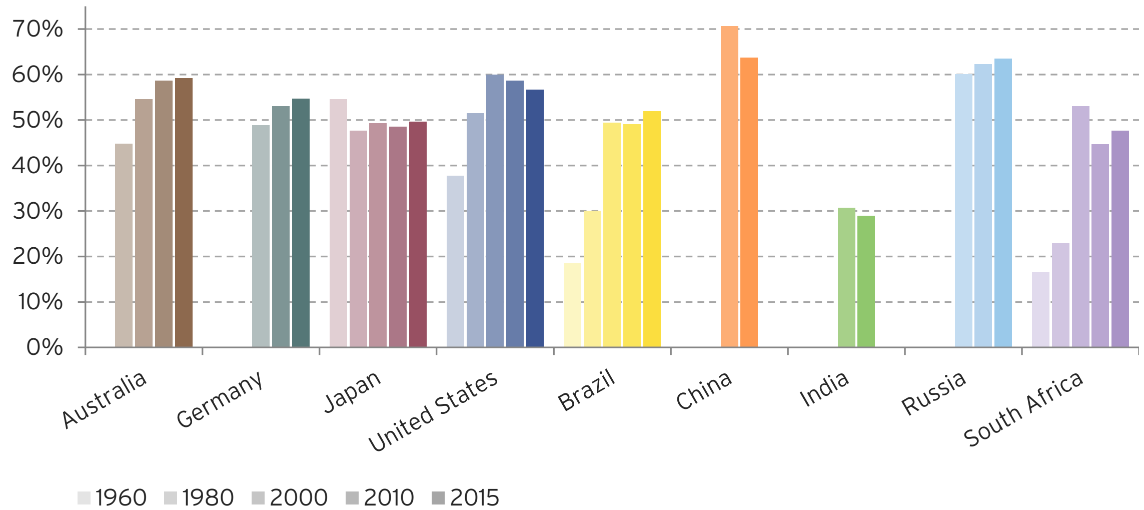


Figure 2.2. Share of Female Labour Participation (% of Female Population Aged 15+) (National Estimate)

SOURCE: World Bank (2019).

2.1 Active Population

2.1.1 Australia

The share of working age population in Australia is one of the highest in OECD countries (increasing from 65% in the 1950s to 68% in 2010). However, this share started to decline in 2010 and it is projected that the active population will further decline in the coming decades owing to the ageing of society. In 2050 the share of the population aged 15–64 will have declined to 59% (KC & Lutz 2017; Riahi et al. 2017). With regard to the female workforce participation, this has seen a steady increase in the past in Australia, and has reached 59% in 2015, up from 45% in 1980.

2.1.2 Germany

Germany has had a relative steady share of working age population in recent decades, at around 66%. As the baby boomer generation hit retirement, this share started to decline and is projected to reach 54% in 2050. The share of female labour participation increased as well from below 50% to 55% in 2015. Germany thus faces challenges as a result of the ageing of its society and the declining active population. To counter this, the retirement age in Germany is being raised.

2.1.3 Japan

In Japan the trend of an ageing society has been visible since 1990, at which point the share of the age group 15–64 reached 70%. Since then, this share has declined and is projected to further decline to 50% in 2050. This is driven largely by demographic change, with an ageing population characterised by both high life expectancy and low fertility rates. The share of female labour participation in Japan is, at around 50%, relatively low for a developed country. After declining in the 1960s it has remained relatively stable over recent decades. Japan faces strong challenges if it is to maintain its high standard of living, owing to the advanced stage of ageing seen in the country. This might be countered by an increasing share of female labour participation in the future.

2.1.4 United States

The share of working age population in the United States had previously been relatively stable at a little over 65%. However, in the United States also, the baby boomer generation has now reached retirement age, and the share of active population began to decline in 2015. The forecast by IIASA indicates that in the United States this population will have reached a share of 60% by 2050. The share of female labour participation saw a rapid increase in the period 1960 to 2000, from 38% to 60%. Since 2000 it has been gradually declining. The society's response to the demographic ageing is, as in Germany, to raise the retirement age.

2.1.5 Brazil

Brazil's share of working age population has increased steadily over recent decades and reached 70% by 2015. Starting from 55% in 1950, this increase was the strongest seen in the BRICS countries. However, a plateauing can currently be observed, and the share is forecasted to decline to 62% in 2050. The share of female labour participation reached 52% in 2015, from a very low base of below 20% in 1960. Besides the official figures, Brazil has a high share of informal employment and thus female labour participation may be higher in reality.

Brazil, with its low fertility rates, belongs to the late-dividend country group. Its population structure therefore indicates a potential for entering the late-dividend phase. However, particularly between 1980 and 2000, economic development was unstable and Brazil spent the 1990s restructuring its economy. Thus, the opportunities arising from the early-dividend phase could not be realised entirely, diminishing the chances of long-lasting prosperity through the late-dividend phase, unless labour productivity or female workforce participation can be increased substantially (Berlin Institute 2015; World Bank Group 2016). As a consequence, it is expected that retirement age will be raised.

2.1.6 China

China's population is still increasing at present, although signs of the transition to an ageing society are visible. The share of China's working age population has peaked in around 2010 at a level of 73%. It is projected to decline to 61% by 2050. The share of female labour participation has declined in recent years, probably because of the increasing wealth of households.

As with Brazil, China belongs to the late-dividend type of country. Its successful economic growth in recent years may enable China to invest into productivity gains and to prepare for an ageing society. China will also raise the retirement age, and a longer active working life for older people is thus expected.

2.1.7 India

India belongs to the early-dividend group, meaning that in parallel with an increase in the number of people of working age, the fertility rate is declining and is expected to sink to the replacement fertility rate (World Bank Group 2016). Its active population has been increasing from below 60% pre-1980 to 66% in 2015. Still on the rise, it is expected to peak somewhere around 2030. The share of female labour participation on the other hand is, at 29%, low, and is further declining.

As a country in the early-dividend period, India has the chance to prosper, if productive job creation can exceed population growth. Despite notable economic growth, poverty in India is still a major problem and affects a large total number of people. Informal work plays a significant role in India and unemployment is a major societal concern.

2.1.8 Russia

Russia has a high share of working age population – it peaked around 2010 at 72%. However, working age population is expected to decline with the ageing of society to approximately 62% by 2050. The share of female labour participation has increased from 60% in 2000 to 63% in 2015.

Russia is a late-dividend country on a journey of transition to a post-dividend country. Its overall population is expected to decline as it also sees the increasing ageing of its society. The share of citizens aged 65+ is expected to increase, although not reaching the proportions forecast for China and Brazil. As for future development, a raising of the retirement age can be expected; migration of labour to Russia may also play an important role, determining the active population in the future.

2.1.9 South Africa

South Africa is in a phase where it is experiencing both an increasing population and an increasing active workforce. The share of working age population increased from around 55% in 1960 to 66% in 2015, and is expected to increase to nearly 70% in 2050. The share of female labour participation was very low until the year 2000, and currently stands at something between 45% and 65%, depending on the source of estimates, the lower being made by national agencies and the higher by the International Labour Organization. Both unemployment and informal work play a significant role.

South Africa is, like India, an early-dividend country and thus has the chance to prosper, if productive job creation can exceed population growth. However, as a legacy of the apartheid policy, the country still struggles with extreme poverty, and especially with inequality. While the workforce is growing, access to productive jobs remain an issue, with unemployment in recent years running at between 20% and 25%. Furthermore, South Africa has been suffering from an HIV/AIDS crisis and suffers from comparatively low life expectancies. South Africa's ability to harvest the benefits from the early-dividend phase depends on new job creation, coupled with improvements in education and productivity (Schellekens 2016).

2.2 Spatial Dispersion

Spatial dispersion in a broad sense refers to the geographic and sociodemographic structures in a country. Those characteristics may have a profound influence on the levels of motorisation. They also vary greatly from country to country and pose difficulties of interpretation. For example, the overall population density in the study countries ranges from 3 (Australia) to 390 (India) persons per square kilometre. The low population density in Australia is, however, not very useful if interpreted at face value, because its population and its economic activity are both concentrated in only a fraction of the countries' surface. A similar situation obtains, for example, in China, Brazil and Russia. Thus the factor spatial dispersion in this study focuses more on urban areas.

We chose two numeric indicators to explore the development trends of spatial dispersion in the study countries: the percentage of the population living in cities with 300,000 or more inhabitants (UN DESA 2018, Figure 2.3), and the density in the core built-up areas of cities (Angel et al. 2016, Figure 2.4). The first is an indication of the prevalence of urban agglomerations in the country, and the second indicates to what extent the urban spatial structure fosters the use of cars or hinders it. Kenworthy (2018) points to a clear inverse correlation between urban density and the energy used for transport. This relationship is, however, strongly logarithmic and, especially when urban density falls below 40–50 persons per hectare, a strong increase in car use can be observed. At the same time, an inverse relationship between car use and public transport use can be observed (Kenworthy 2018). Thus, low urban density fosters the uptake and use of cars.

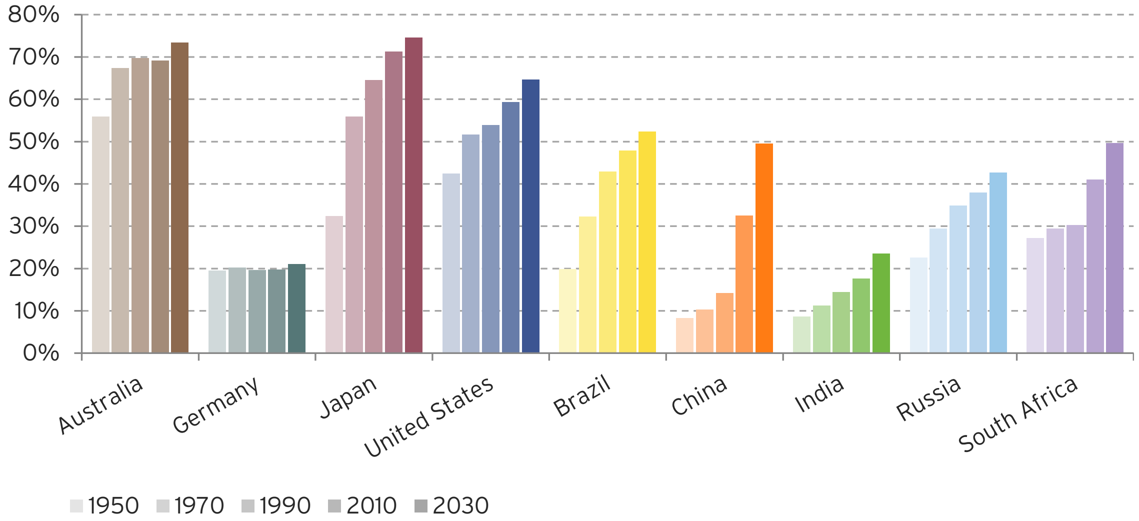


Figure 2.3. Percentage of Total Population Residing in Urban Agglomerations with 300,000 Inhabitants or More

SOURCE: UN DESA (2018).

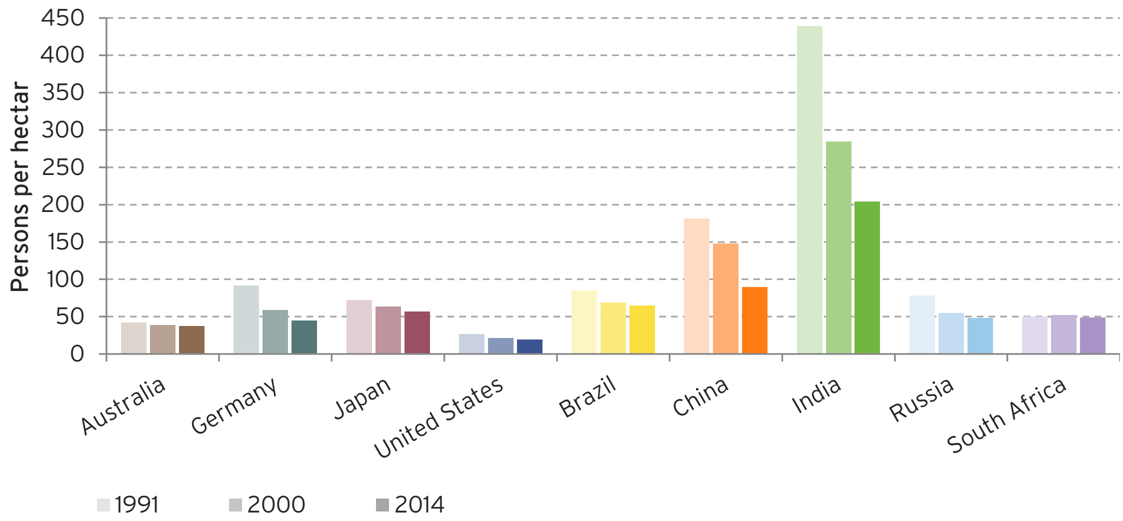


Figure 2.4. Density of Urban Built-Up Areas

SOURCE: Angel et al. (2016).

2.2.1 Australia

Australia's population is located primarily on the periphery of the country, with the highest concentration of people residing in the southeast. A secondary population centre is located in and around Perth in the west. Of the States and Territories, New South Wales has, by far, the largest population; the interior – the outback – has a very sparse population (CIA 2018). Its urban development started from a hub-and-spoke system and expanded into low-density suburbanisation. The density of urban built-up areas is low at 37 persons per hectare, but stable. In recent years, the use of foot and bicycle has seen a strong increase, partially owing to a growing health awareness among citizens.

2.2.2 Germany

Germany is the most populous country in Europe, with a fairly even distribution of the population throughout most of the country. Urban areas attract larger and denser populations, particularly in the far western part of the industrial state of North Rhine-Westphalia (CIA 2018). However, Germany is also characterised by many smaller cities and well-developed and connected rural areas. Only 20% of the population lives in cities of over 300,000 inhabitants, but many cities form metropolitan areas such as in the Rhine-Ruhr region. The density of urban built-up areas has been steadily declining and is now reaching levels of 40 persons per hectare.

2.2.3 Japan

All primary and secondary regions of high population density lie on the coast; one third of the population resides in and around Tokyo on the central plain (the Kanto Plain) (CIA 2018). Thus, the share of people in cities larger than 300,000 inhabitants is the highest among the four OECD countries. Similarly, the density of urban built-up areas is the highest, although it has been declining in recent decades.

2.2.4 United States

The population in the United States concentrates in large urban clusters throughout the eastern half of the country (particularly the in the Great Lakes area, and the northeast, east, and southeast) and the western tier states. Vast areas in the centre of the country are less densely populated (CIA 2018). Nearly 60% of the population lives in cities of over 300,000 inhabitants. However, the density of urban built-up areas is very low at 19 persons per hectare, and has declined continuously over recent decades.

2.2.5 Brazil

The vast majority of people live along, or relatively near to, the Atlantic coast in the east; the population core is in the southeast, anchored by the cities of São Paulo, Brasília, and Rio de Janeiro (CIA 2018). Brazil had by the 1930s already started to develop from an agricultural to an industrially oriented society, and a period of rapid urbanisation began (Pojani et al. 2017). About 50% of the population now lives in cities with more than 300,000 inhabitants, and the density of urban built-up areas is, at 65 persons per hectare, relatively high. However, Brazil went through several economic crises, and the spatial structure has developed in a highly differentiated fashion that is based on patterns of wealth. While central areas in cities have access to good infrastructure, large marginal areas for the poor and gated communities for the rich area a feature of Brazil's conurbations. People on low incomes generally have little access to cars, and have to cope with a lack of good infrastructure for public transport, walking and cycling. People in gated communities, on the other hand, rely heavily on the private car (Pojani et al. 2017). The current policies indicate that this inhomogeneous spatial structure will not be resolved in the foreseeable future.

2.2.6 China

The overwhelming majority of the population of China lives in the eastern half of the country. The western half, with its vast mountainous and desert areas, remains sparsely populated. High population densities are found along the Yangtze and Yellow River valleys, the Xi Jiang River delta, the Sichuan Basin (around Chengdu), in and around Beijing, and in the industrial area around Shenyang (CIA 2018). China is characterised by a strong increase in urbanisation in recent decades. Since 1990 the proportion of the population living in cities with more than 300,000 inhabitants has doubled. At the same time, the density of urban built-up areas has dropped from a notable high of 180 persons to 90 persons per hectare. The cities generally spread outwards, and people settle increasingly in the suburbs, partially as a result of resettlement policies. Additionally, surrounding the cities are villages for migrant workers who cannot afford the cost of living in the central urban areas (Pojani 2017). The traditional cities in China were built for using bicycles or walking as the normal way of getting around. However, as wealth has risen, the ownership and use of cars has become prevalent, and in recent years many cities have experienced congestion. To cope with its spatial developments, China is intervening strongly in the planning process with regard to housing and transport.

2.2.7 India

With the notable exception of the deserts in the northwest and the mountain range in the north, a very high population density exists throughout most of the country. The population concentrates along the Ganges river, with other river valleys and southern coastal areas also having large concentrations of people (CIA 2018). India's population is thus much less concentrated in urban areas than is the case in the other BRICS countries. On the other hand, the Indian countryside contains a network of smaller cities that offers potential for development. The density of built-up areas is also rapidly declining, but with over 200 persons per hectare remains the highest among the BRICS countries. Peripheral growth is being tolerated, and cities are spreading outward. While the rich population concentrates in urban centres and planned districts, fewer of the privileged people are spread over the cities as a whole, and in the peripheral regions (Pojani et al. 2018). The urban structures favour the use of two-wheelers, bicycles and walking. Nearly all cities see a strong growth in their total population. As a consequence, vehicle speeds in Indian cities can be very slow.

2.2.8 Russia

The vast majority of Russia's population lives in the western part of the country, in the region stretching eastward to the Ural mountains. Some isolated urban agglomerations are found in the south, towards the border with Kazakhstan. According to official figures, nearly 40% of the population lives in cities of 300,000 inhabitants or over. Of the remaining population, a majority also lives in smaller urban settlements. Those grew predominantly around industrial areas during the Soviet period. Suburbanisation has taken place, in particular driven by the movement of Russian elites (Pojani et al. 2018). The density of built-up areas has declined to below 50 persons per hectare. Especially since the 2000s, a lack of spatial planning can be observed, with the consequence that housing and economic activities are disintegrating.

2.2.9 South Africa

The population of South Africa is concentrated along the southern and south-eastern coast. Another demographic centre is the capital city of Pretoria in the north-west of the country. The western part is generally less populated, except for the Cape Town region. South Africa continues to suffer from the heritage of the apartheid system – in particular, the cities are fragmented and separated along the lines of ethnicity and wealth. Generally, a radial system of transport networks is found (Pojani et al. 2018). Urbanisation rates have picked up since 1994, the end of apartheid, and they are expected to increase further. The density of built-up areas is, at around 50 persons per hectare, fairly stable. However, as mentioned, the distribution of populations in cities is somewhat heterogeneous and reflects large income and wealth disparities.

2.3 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 2.5), but Australians own more cars than either Germans or Japanese." (Ecola et al. 2014: 50) In comparison to the OECD countries, only China's car industry plays a significant role, as it has increased its vehicle production considerably since 2015 to more than 22 million vehicles a year. India on the other hand has a strong supply industry for car manufacturers, as well as a large volume of two- and three-wheeler production.

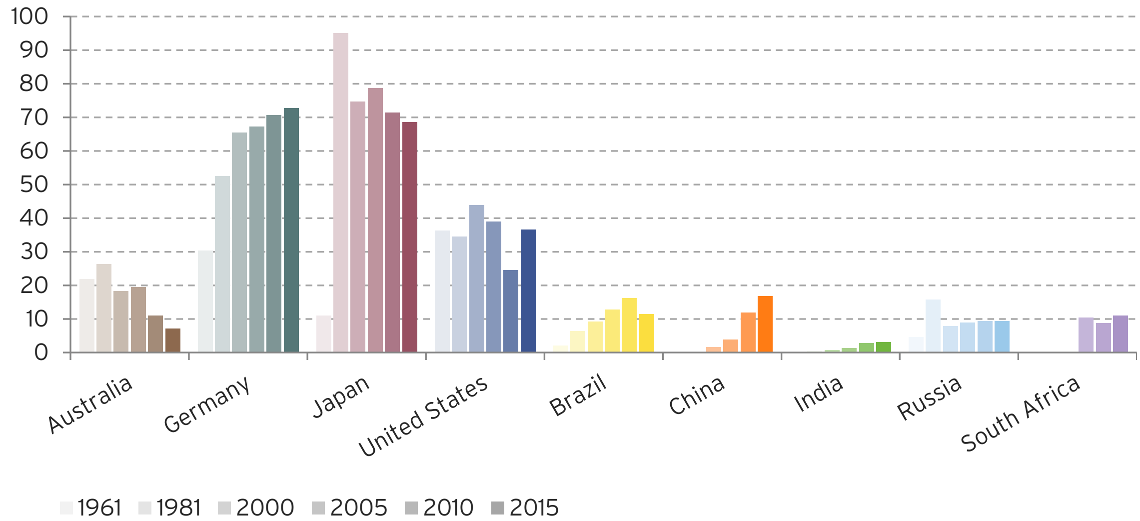


Figure 2.5. Number of Motor Vehicles Produced per 1,000 Population

SOURCE: Vehicle data: until 1981 U.S. DOT – BTS (2018), from 2000 OICA (2017); ***population data****: UN DESA (2018).*

NOTE: Figures include passenger and light commercial vehicles.

2.3.1 Australia

Australia has a small car industry, and its importance for the country's economy has declined steadily since the 1960s. Production figures, which have been declining since the 1970s anyway, reached a low point in 2016 with only 156,000 vehicles (Ecola et al. 2014: 51; U.S. DOT – BTS 2018, Table 1-23). In the long run, the car industry is expected to disappear.

2.3.2 Germany

Starting in the late 1800s, the automotive industry in Germany developed into one of the most important branches of the nation's industry. After the Second World War, production figures rose rapidly, and by the early 1960s more than two million vehicles were being produced per year. After a rapid increase until 1990, the German automotive production increased slower to more than 6.2 million vehicles in 2016, making Germany the world's fourth-largest manufacturer (U.S. DOT – BTS) 2018, Table 1-23). At the same time, the automotive industry is the country's largest employer, with more than 800,000 employees in 2017 (DESTATIS 2019), accounting for almost 2% of the total workforce (DESTATIS 2018: 356). Regardless of its importance for the domestic market, in terms of both vehicle sales and workforce, the German automotive industry is extremely export-oriented; in 2017 the export ratio for passenger vehicles was 77.5% (VDA 2018). So far, however, it has relied primarily on conventional automobility and technologies. More recently, a shift towards hybrid and electrified vehicle technology can be observed.

2.3.3 Japan

The Japanese car industry developed comparatively late, only really developing from the 1920s, in the slipstream of subsidiaries of U.S. manufacturers assembling imported car components. It was only after the implementation of protectionist legislation in the mid-1930s that domestic manufacturers gradually began to flourish. The industry was initially strongly oriented towards Fordist principles of mass production, but since the 1960s innovative production and management concepts (such as just-in-time, lean, and quality control) have been increasingly been applied (Elis 2009). Although vehicle production figures are declining, Japan is still the third-largest producer worldwide (OICA 2017). Just as in Germany, the Japanese automotive industry is export-oriented and has long relied predominantly on conventional technologies complemented by advancements in hybrid and fuel cell technologies.

2.3.4 United States

With the introduction of innovative Fordist production concepts in the early 1900s, the United States quickly became the leading car-producing nation. However, in the aftermath of the oil crisis of the 1970s, U.S. American car manufacturers faced new competitors from other countries that managed to adapt quickly to changing consumer preferences for smaller vehicles. Despite a considerable slump in production figures around 2009, after a subsequent recovery (U.S. DOT – BTS 2018, Table 1-23) the United States still ranks second among the largest producers after China (OICA 2017). As in Germany and Japan, the US automotive industry still relies heavily on conventional technologies, but it is dissimilar in being focused primarily on the domestic market.

2.3.5 Brazil

Although Brazil does not come close to the traditional production countries in absolute volume terms, it still ranks ninth among the largest automobile manufacturers. While growth rates up to 2013 were considerable, production figures have been falling since then (U.S. DOT – BTS 2018, Table 1-23), a trend which the experts consider to be temporary.

All major car manufacturers are represented in the country. Given a weak domestic market, there is a strong export orientation, especially towards developing countries (Richarz 2018). The country's developing car industry promotes automobility as well as investment in new technologies (e.g. a powertrain and battery pack for electric trucks).

2.3.6 China

Compared to the situation in traditional producer countries, the Chinese automotive industry is a fairly new phenomenon. It developed after the Second World War, initially supported by the USSR, and has flourished – particularly since the late 1970s, thanks to the gradual economic reforms that began at that time. While initially focused exclusively on a selected domestic market, it has developed rapidly since then because of considerable "market interventions by the Chinese government in an effort to develop its 'pillar' industry" (Deng & Ma 2010: 842). Similarly to Brazil, major foreign car manufacturers are represented in China as part of joint ventures.

Since 2009, China has ranked first among the world's car-manufacturing countries (OICA 2017). However, there are initial signs that this enormous growth is slowing down, and that production figures are beginning to decline. R&D investment in the automotive sector are increasing, but at a much lower level than in the EU, Japan and the United States (ACEA 2019). In particular the development and deployment of electric vehicles is strongly supported by the government, but faces the same barriers to uptake as in the West (Howell et al. 2014).

2.3.7 India

Although dating back to the 1940s, it was not until the 1970s that the Indian automotive industry began to develop significantly, the early hindrance being because of import policies initiated by the government. Production was initially dedicated primarily to commercial vehicles and two-wheelers, with the latter still dominated to this day by domestic manufacturers, and focused on fuel-efficient, low-performance vehicles.

As with Brazil, India's volume figures do not come close to the traditional production countries in absolute terms, but it nevertheless ranks fifth among the car-manufacturing countries (OICA 2017). Two- and three-wheeled vehicles account for a significant proportion of vehicle production; in addition to this, the manufacturing of car parts, including diesel technologies, plays an important role. In the future, electric vehicles will gain importance. Consequently, India has a high and increasing proportion of diesel vehicles, resulting in increasing tax revenues from diesel sales compared to petrol (MORTH 2016).

So far, Indian vehicle production has focused only to a small extent on exports, with around 70% of production designated for the domestic market. However, this ratio is expected to shift, albeit slowly, in favour of exports.

2.3.8 Russia

Beginning after the 1917 October Revolution, and with its first upheaval in the 1930s, it was only after the Second World War that the Russian car industry developed into a significant part of the country's industry. In the early 1990s, however, after the dissolution of the Soviet Union, car manufacturers were severely affected by the overall turmoil and new competition in a worldwide market, resulting in declining production figures. They started to recover slowly afterwards, with a peak in 2012. Vehicle production is now declining again (U.S. DOT – BTS 2018).

Nevertheless, the automotive industry is a governmental issue of highest relevance, not least because of its importance for the domestic labour market. The Russian car industry still produces both own and foreign brands, but the share of domestic brands is declining. In terms of production figures, Russia ranks 15th worldwide (OICA 2017).

2.3.9 South Africa

Compared to the other study countries, South Africa has no relevant automotive industry, even if vehicle and component production accounts for about 30% of the domestic manufacturing output (South African Government 2018) and therefore is considered by the government to be of major importance. In terms of absolute figures it ranks only 22nd among car-manufacturing countries (OICA 2017).

Domestic production is dedicated mainly to conventional commercial vehicles, while passenger cars are produced under license for foreign brands, which have been represented in the country since the 1920s. Exports of automotive products account for about 14% (2017) of all exports (South African Government 2018).

2.4 Car Infrastructure

The factor car infrastructure indicates the quantity and quality of infrastructure in place for road driving. It essentially indicates how fast, comfortably and safely a person can reach a destination by car. This also takes into account the ability to park. One indicator of car infrastructure is the length of roads in a country in relation to its population. In Figure 2.6 we allocated this length of roads to the fraction that passenger transport represents of all road transport in the country. We hereby considered the total countries' passenger kilometre and freight tonne kilometre by road transport (ITF 2017) and assumed that each passenger kilometre requires 2.5 times the infrastructure length of a tonne kilometre freight. In addition to some questionable data, official data on this factor are of limited value, since the sheer length of roadways does not necessarily tell anything about the conditions for travelling on them. Furthermore, besides the length and number of lanes, other aspects, including traffic management, play a role in making for comfortable and safe driving. Data on parking capacities and the balance between car and non-car infrastructure are likewise missing. An additional indicator for car infrastructure is the country ranking by the World Economic Forum (WEF) with regard to infrastructure (Figure 2.7). However, in view of the unsatisfactory nature of any figures available, the factor car infrastructure heavily relies on the expert input.

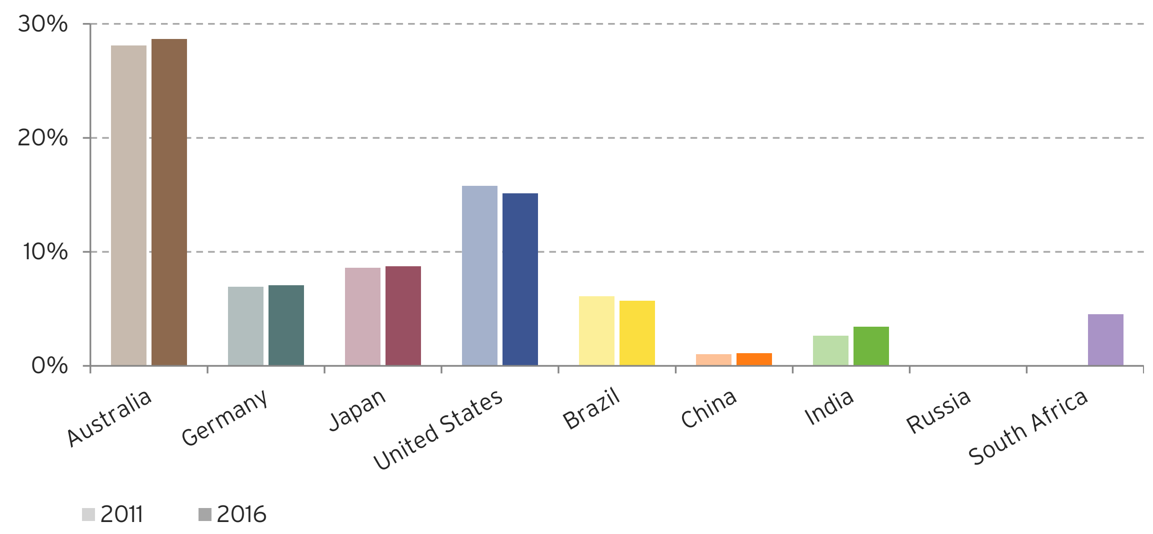


Figure 2.6. Total Road Network in Centreline Metres per Population Related to Passenger Transport

SOURCE: CIA (2018), OECD & ITF (2017).

NOTE: Percentage passenger transport calculated on the basis of data on total passenger-kilometres and tonne-kilometres.

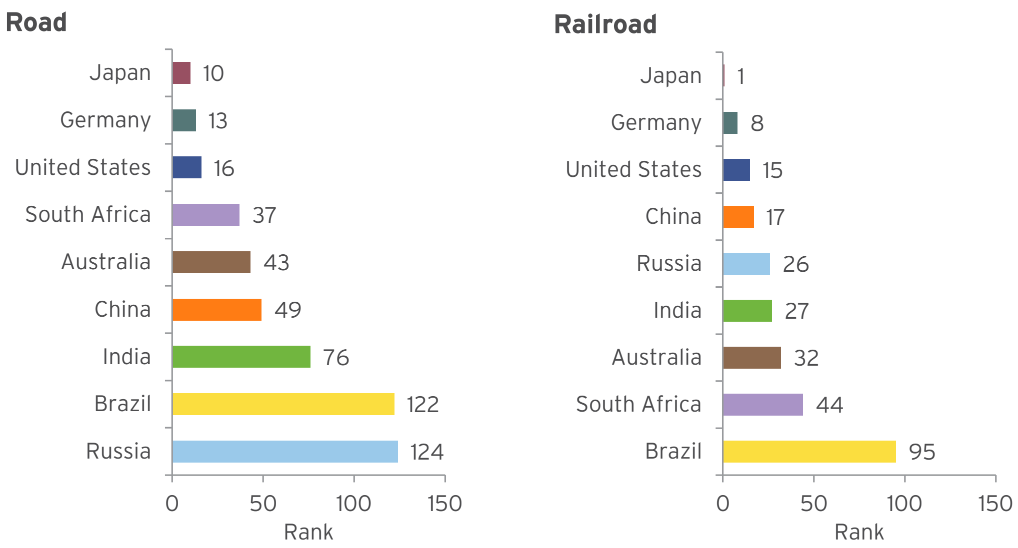


Figure 2.7. Quality of Road and Railway Infrastructure – Country Ranking

SOURCE: WEF (2014).

2.4.1 Australia

Australia has the largest road network of all OECD countries. However, it also has the highest percentage of unpaved roads. The construction of highways and federal roads picked up in the 1970s. Recently the infrastructure for non-car modes in urban areas has been improved.

2.4.2 Germany

Germany, second only to Japan, has the highest coverage of paved road infrastructure in terms of total surface area. Germany's legacy of road-focused infrastructure investment began in the 1930s and saw two additional phases of massive infrastructure investment: in the years of nation-building after the Second World War, and in the years after the reunification of East and West Germany in 1989. It was usual for investment in non-car infrastructure to be accompanied by investment in the road infrastructure. This has been one of the main reasons why Germany is still to this day a car-friendly society, despite policy goals designed to shift automobility to non-car transport modes. According to the WEF, Germany's road infrastructure ranks 13th globally and second among the four OECD countries (WEF 2014). In recent years the construction of bicycle infrastructure has gained momentum.

2.4.3 Japan

Japan as well has a very high coverage of paved road infrastructure compared to its total surface area. However, the build-up of road infrastructure started only in the 1960s and 1970s. Parking in Japanese cities is limited and very expensive. Nonetheless, road infrastructure is ranked tenth globally, and it is the highest ranked among the four OECD countries (WEF 2014).

2.4.4 United States

The United States has the second-largest road network of the four OECD countries. Most of the roads are paved, and parking is generally plentiful, even in larger cities. Exceptions to this are seen in some metropolitan areas, like New York and San Francisco, where parking is limited and very expensive. The road construction-up goes back to periods in the 1920s and 1930s and another period in the 1950s and 1960s. Since 1970 few new roads have been added, and the car infrastructure is now deteriorating to some extent. Its road infrastructure is ranked 16th globally, behind Germany (WEF 2014).

2.4.5 Brazil

Brazil has a large road infrastructure, but problems with regard to its quality. Only 18% of it was paved in 2012 (Amann et al. 2016). The WEF ranks Brazil's road infrastructure at 122nd, the second-lowest rank of the BRICS countries (just ahead of Russia). Furthermore, the road infrastructure differs from region to region. While roads in the south and south-east are generally well served with sufficient infrastructure, the quality of road infrastructure in the north, north-east and centre-west is poor (Amann et al. 2016). Despite the deficiencies in road infrastructure, the mode share of the car has increased constantly, and cars are the dominant mode of transport, even in large metropolitan cities.

2.4.6 China

China's road infrastructure is rapidly expanding, but began at a low level. China has invested greatly in its road infrastructure, particularly since the late 1990s. While the focus of the construction of road infrastructure lies in the eastern part of the country, investment includes also hinterland connections and investing in the new Silk Road from Asia to Europe. One deficiency in China remains parking in urban centres. Recently, China has also increased its efforts to supply urban infrastructure for cycling and walking. The WEF ranks China's road infrastructure at 49th, behind that of Australia and therefore catching up with road infrastructure qualities of developed countries.

2.4.7 India

India has a very dense road network, and during recent years much effort has gone into the construction of road infrastructure. The total length of the national highways has tripled between 1990 and 2015 (Lokesha & Mahesha 2017). However, there are deficiencies, in particular when it comes to the quality of rural roads, which are under responsibility of regional governments. About 40% of the road network is not paved. The parking supply is also very limited, and the urban density of large cities does not favour a rise in car usage. Congestion in Indian cities, resulting from density and the nature of the infrastructure, is a major dampening influence on motorisation (Verma et al. 2015). This may be one reason why two- and three-wheelers are very popular in the country. India's road infrastructure is ranked 76th globally according to WEF (2014).

2.4.8 Russia

Russia's road infrastructure is divided into that found in the densely populated areas, and that which services the vast areas of the country with low population density. The infrastructure supply in the later is poor. Furthermore, the basic road infrastructure stems from the Soviet era, when traffic levels were much lower. In the period 1990 to 2015, there was insufficient focus on the construction of infrastructure. According to the WEF (2015), Russia ranks 124th in road infrastructure, the lowest ranking of the BRICS countries. Recently a reorganisation of the road network was announced, bringing more roads under federal jurisdiction. Additionally, the Russian government has announced large investment programmes for infrastructure, including roads (Russia Business Today 2019).

2.4.9 South Africa

South Africa has a comparatively good road infrastructure. In the WEF ranking, South Africa ranks 37th, the best rank of the BRICS countries, even surpassing Australia. Additionally, government policies require the provision of adequate road infrastructure for each new settlement. Only the country roads in rural South Africa are often unpaved. Moreover, parking in cities poses no great problem.

2.5 Lack of Alternatives

The factor lack of alternatives aims to capture the availability of alternatives to the private car. These can be manifold: certainly urban public transport and national rail are alternatives, as are public bus services. However, in many emerging countries, informal services also exist, and these can provide significant levels of alternative transport offerings. Thus, this factor can not be fully captured by statistical figures alone.

Figure 2.8 is derived from just such statistical figures, and provides some indication of alternatives to the car for OECD countries in recent years, but it should be handled with care for the BRICS countries because it includes only public transport services offered by official transport service providers. Unfortunately, no data was available for India and South Africa. Additionally, to shed further light in our quest to assess the national alternatives to the car, we have compared the national VKT by rail with that by car (ITF 2017). From this we derived the shares of passenger kilometres by road and rail respectively, if available.

Another difficulty in grasping this factor is its geographic scope. On the one hand we are interested in national indicators of alternatives. As Ecola et al. (2014) stated, the percentage of the population with access to public transport may be one such indicator – the Americans are the least likely to have access, while Germans are the most likely. On the other hand, cities, and the provision of urban transport alternatives within them, are also of great importance for understanding alternatives – and the more the productivity of a country is associated with its urban centres, the more relevant this becomes. This factor should therefore be read in conjunction with the factor spatial dispersion.

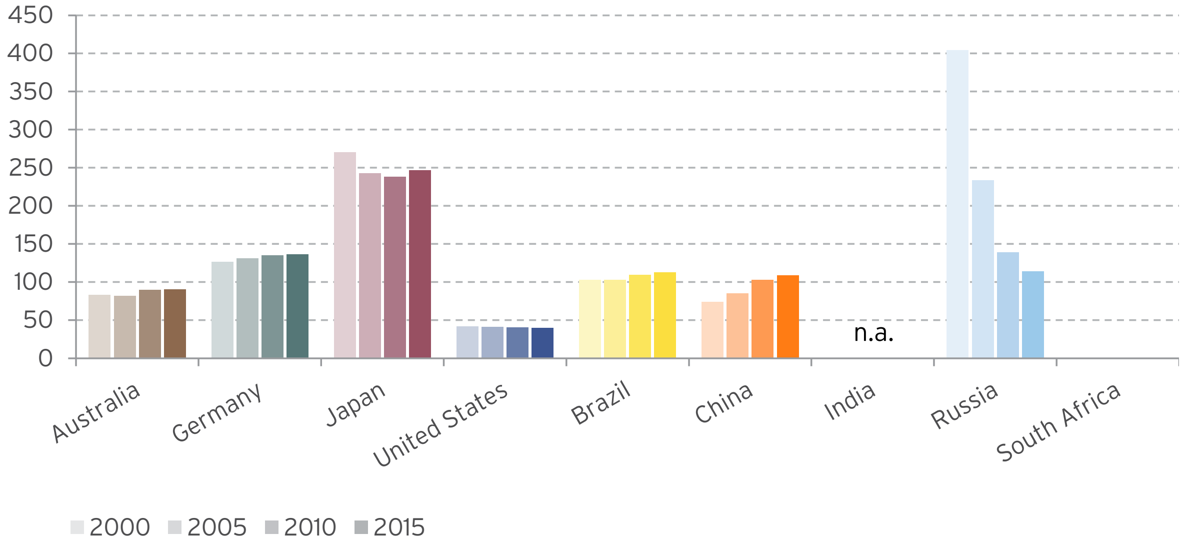


Figure 2.8. Urban Public Transport Journeys Per Capita Per Year

SOURCE: UITP (2016).

NOTE: Only official urban transport services are shown, and this excludes commuter rail services.

2.5.1 Australia

Australia's large cities are well served with rail connections and inner-urban light rail or bus services. Rail connections exist between the big urban centres (Ecola et al. 2014). However, the long-distance rail connections are comparatively slow and expensive. Of the overall demand for transport, only 5% is served by rail (nationwide). Australia's government has announced an investment programme into the rail system worth 10 billion AUS$, which includes support for faster connections between capital cities and regional centres (GIZ 2018).

Additionally Australia's cities are currently seeing a significant revival of walking and cycling. This is being encouraged in large part by a drive for healthier lifestyles, but has had the effect of reducing car use and increasing public transport use in cities (expert guess). This is also confirmed by a slight increase in public transport trips per capita.

2.5.2 Germany

The history of non-car modes in Germany goes back a long way, both with regard to public transport technologies and infrastructure, and in terms of planning measures designed to promote walking and cycling (Ecola et al. 2014). The spatial structure that is determined by an evenly distributed large number of small- to medium-size cities enables a good public transport system, but at the same time hinders some features, for example a nationwide rail service running to regular interval timetables, which is easier implemented in countries with few urban agglomerations. Nonetheless, the number of public transport trips per capita is the second-highest among the study countries (UITP 2016) and rail passenger-kilometres make up 9% of the total national passenger-kilometres. However, in recent years the German rail system has suffered under austerity measures, and has lost some service quality as a result. This, alongside a good car infrastructure, has kept the alternatives to automobility at a level that is beneath their potential. Planned investments in the public transport infrastructure may foster the use of alternatives in the future.

2.5.3 Japan

Japan too, has a long history of public transport and a very good urban and intercity rail infrastructure. With its spatial characteristics, high urbanisation rate and comparatively dense built-up areas, Japan is well suited to providing public transport services. It has the highest number of public transport trips per capita of our study countries, and more than 30% of total Japanese passenger-kilometres are travelled by rail. Additional government plans in the light of global climate change (e.g. the Low Carbon City Promotion Act, known as the 'Eco-City Act') aim to further promote the use of public transport options. Furthermore, subsidies and tax incentives have been implemented to promote the construction and use of public transport systems (GIZ 2018).

2.5.4 United States

Public transport in the United States is the less accessible than in the other three OECD study countries. There are differences within the country – in particular, large cities (e.g. New York) tend to have good public transport networks, whereas smaller cities often offer no more than limited bus services. Development in large parts of the United States is car-oriented, and the infrastructure supporting alternatives to the car – including walking and cycling – lacks quality (Ecola et al. 2014). The level of public transport trips per capita is the lowest among our study countries, and has, moreover, declined in recent years. Public transport in the United States is facing concerns as to its status and its security, as its use is associated with those on low incomes. What is more, additional individual transport services may put further pressure on public transport. This is despite the introduction of some (mostly city-based) programmes aiming to promote walking and cycling and investing in rail and bus services.

2.5.5 Brazil

Public transport in Brazil relies heavily on bus systems, both inner-urban and extra-urban. In recent years bus rapid transit (BRT) systems have been introduced, but these are inadequate in terms of reliability and quality. While Brazil did invest strongly in the public transport infrastructure to prepare for the soccer World Cup and the Olympic Games, accessibility to public transport is variable. In central urban districts the supply is usually good, whereas marginal areas, particularly those inhabited by the poor, are inadequately served. Furthermore, large income disparities make public transport very expensive for large segments of the population. Gated communities also lack good access to public transport. In contrast to official policy statements, the quality of public transport has been deteriorating, as also has the demand for it in recent years (expert guess). In some areas there are informal offerings based on motorcycles and cars, but cycling and walking, despite the rather poor infrastructure servicing them, are often the only alternatives to bus and car.

2.5.6 China

China certainly stands out in its efforts to improve public transport infrastructure, both within urban agglomerations and between cities. Traditional Chinese cities were organised around the use of bicycles. Rapid motorisation has led to significant congestion levels, and policies favouring public transport are countering this. The urban rail and metro system has expanded substantially in the past decade, owing to a number of financial development plans (Gao et al. 2018). Additionally, a resurgence of the bicycle, in the form of electric bikes and bike sharing, can be observed, as can the promotion of all forms of two-wheelers. The provision of urban alternatives to the private car is often combined with regulations restricting private motorisation and its use. Wu et al. (2016) argue that in many metropolitan areas motorisation saturation levels have already been reached.

China has also made very large investments in national rail. By 2017, 25,000 km of rail tracks connected over 200 cities, mostly in the central and eastern provinces. Of this system, half is built for high-speed services. An extension bringing the total to around 38,000 km in 2025 is planned (Bullock et al. 2014). Based on official statistics, the VKT by rail are equal to that of car travel. However, the users of long-distance rail are predominantly under the age of 40 and mostly male, probably as a result of the cost.

2.5.7 India

In the two large metropolitan cities of Delhi and Mumbai, good levels of public transport, including metro rail, are in place. In other cities, the metro systems are still at an early stage of development. Most public transport trips are made by buses, but bus services are decreasing. The construction of infrastructure cannot keep pace with the growth of cities. Other alternatives to the car that are in widespread use are the two- and the three-wheeler, whether for hire privately or as informal public transport offerings. Walking and cycling are also prevalent in India. With regard to long-distance transport, India has a countrywide rail infrastructure, but one which lacks in quality. A plan to expand the rail network to 25,000 km is progressing, but sluggishly. Only 13% of India's passenger-kilometres are travelled by rail, and this is trending downwards. However, the government aims to strengthen public transport as an alternative to the car, which means that it can be expected to grow in relevance.

2.5.8 Russia

Russian public transport has had the opportunity to build on its legacy from the Soviet period. During this time, public transport (in the form of bus, light rail and metro) formed the backbone of citizens' mobility. Since 1990, the use of public transport has declined dramatically, and income disparities and suburbanisation have furthered the deterioration of the infrastructure. Only recently a national strategy aiming to significantly improve the infrastructure and services, including high-speed rail, has been put in place (GIZ 2018). Although use of public transport is declining, the fares are kept low so as to make it accessible to the vast majority of citizens. About 20% of the passenger-kilometres travelled are by rail.

2.5.9 South Africa

South Africa has a comparatively large rail network, but it has not been maintained in the years following the ousting of the apartheid regime. New programmes aim to enhance the rail system, and new settlements in particular are required to supply public transport connections. However, South African public transport also faces concerns with regard to safety, comfort and acceptance by the public. In recent years, BRT systems that compete with local minibus offerings have been installed. Often public transport offerings compete with the same services, and coordinated planning is lacking. The minibus system plays an important part in South Africa's public transport.

2.6 Pro-Car Policies

While infrastructural measures tend to have an indirect influence, dedicated pro-car policies affect car ownership and use more or less directly. These include, for example, vehicle taxes, which, unlike fuel taxes, are not directly linked to consumption; vehicle inspection regulations; road tolls; parking management; and access restrictions applying to certain roads or urban areas.

2.6.1 Australia

Since 1986 the fringe benefits tax, to be paid by employers, has supported car use by employees, as it may help to reduce their taxable income (Australian Government 2019). Up to 2011, besides the basic value of a car, the taxable value was calculated according to a statutory formula on a kilometres-driven basis, resulting in an incentive to use more expensive cars and to drive more kilometres for both business and private use. Since then it has been calculated regardless of distance travelled. Pooled or shared cars, however, are excluded from benefits.

The introduction of graduated driving licences may have had a slightly discouraging effect on car use, as these make younger drivers wait longer and gain further experience behind the wheel before they can become fully licensed than licensing policies which provide a full and unrestricted licence immediately.

Facing increasing demand for parking space, the Australian capital cities, at least, have now adopted parking pricing schemes in their inner-city areas (Gribbin undated).

2.6.2 Germany

As Ecola et al. (2014: 42) already stated, "policies have gone through several shifts from not favouring cars to favouring cars to favouring alternatives." With the onset of economic recovery after the Second World War, and the partition of the country, West Germany increasingly invested in roads and public transport, and tax benefits were introduced for longer commuting trips. In order to support the key domestic car industry after the economic crisis in 2008, a huge, albeit controversial, scrappage programme (the 'cash for clunkers' scheme[5]) was launched in 2009 by the government, resulting in a boost in car sales.

At the same time, as it faces the twin challenges of global climate change and local pollution, the government aims at reducing emissions, and possibly discouraging people from using cars at all. However, most measures implemented thus far – ranging from emission-related taxes on cars in low-emission zones and speed limits in traffic calming zones in residential areas, to cautious infrastructural modifications in favour of public transport or cycling – seem to have had only a limited effect, despite lively public debate on the issue.

In terms of congested inner cities, many of them have introduced parking management zones and related charging schemes. Following a toll system applying to freight vehicles on federal roads, a similar toll for private car use is under discussion and is a subject of controversy, but it has not been launched so far.

2.6.3 Japan

After enjoying major support for automobiles and road infrastructure, Japan today faces the same environmental and social problems as all the world's countries, developed and emerging – pollution, emissions, accidents and congestion, to name the main ones. Similarly to Germany, the automobile industry is an essential part of Japan's economy. Nevertheless, both the industry and car buyers bear high tax burdens by comparison with international norms (Japan Research Center for Transport Policy 2015).

Motor vehicle transport policies are tending towards deregulation. In 2005, the toll road system has been privatised in order to reduce toll costs, following a short period where the complete abolishment of toll roads was considered (Japan Research Center for Transport Policy 2015). A strict regime of repeated costly vehicle inspections results in a high fleet turnover and high export rates of used vehicles owing to rapidly decreasing vehicle values (UNECE ICT, 2017).

[5] A scrappage programme in Germany which ran for the duration of 2009, providing a cash rebate of €2,500 for people trading in cars over nine years old (which were sent to scrapyards) when buying a new one.

2.6.4 United States

According to Ecola et al. (2014) the "US approach to car ownership and driving could probably best be described as laissez-faire". Although the car was invented in Europe, the United States had soon started pioneering car-friendly cities during the first half of the twentieth century. Many factors worked together to lead to the tremendous dominance of the car in the United States (Buehler 2014): low purchase costs (owing to assembly line production), a well-developed high-quality road network, low taxation rates of car ownership, the assignment of tax revenues for the building and maintenance of the extensive road infrastructure (in particular the interstate highways), and, finally, substantial subsidies to promote expenditure on roads. In contradistinction to many countries in Europe, the United States seeks to solve problems arising from negative effects of road transport (such as emissions, accidents and congestion) by means of technologically driven solutions – for example, putting in place an obligation to comply with Corporate Average Fuel Economy (CAFE) standards rather than altering behaviour by applying restrictions to cars (such as reducing speed limits, establishing car free zones, or reducing car parking).

2.6.5 Brazil

Brazilian government policies clearly favour the automobile, mainly in order to bolster the domestic car industry. In line with this aim, high import duties of 35%, as well as other taxes (e.g. IPI, a sales tax on industrial products) are applied to imported cars. In 2012 the Inovar-Auto programme was launched, aiming at stimulating domestic car production through innovation, investment, efficiency and environmentalism. The programme, designed for the five years running up to 2017, "appears to have had a clear impact, allowing domestic automakers to increase their prices, as competition from imports was reduced. This increase in prices added to the already high prices for vehicles…" (Sturgeon et al. 2017).

2.6.6 China

While China for a long time was considered a nation of cyclists, come the mid-1990s, with the onset of economic growth, official policy turned towards the car – not only opting for car production and urbanisation on a grand scale, but also allowing workers to own private cars. The focus, however, was not on individual mobility, but rather on cars as a sign of advanced technological progress. Regional transport master plans regarded cycling as problematic, and adopted measures to reduce use of the mode to pave the way for the arrival of the car – so a pro-car policy arose initially as a bicycle-banning policy. More recently, in the face of the inevitable resulting side effects such as congestion and pollution, policies have shifted once more, now aiming to curb automobility by means of limited licensing, parking regulations and additional investment in public transport. (Oldenziel 2017) At the same time, China is choosing the path of electric drivetrains to combat climate change. The introduction of its 2018 New Energy Vehicle (NEV) mandate, which sets a quota for the number of zero-emission vehicles that carmakers must sell, is part of a long-term strategy to ban cars with traditional internal combustion engines (Steer 2018).

2.6.7 India

Echoing the approaches of other emerging countries, Indian government policies have focused on promoting motorisation to stimulate economic growth, and in particular the growth of domestic car manufacturers. "governments at all levels have concentrated on the expansion of roadway capacity to accommodate the increased volumes of private motorised travel [...] taxes and fees for car purchases, registration, parking, and licensing are generally quite low, thus facilitating the affordability of cars. All three policies clearly favour motorised over non-motorised travel, making more and cheaper cars available, providing more extensive rights of way to use them on, and making car use itself relatively cheap by minimising taxes and fees." (Pucher et al. 2007: 397).

Although their implementation has by no means extended across the whole country, active policies for curbing and regulating car-based mobility as a result of environmental concerns and energy shortages are in place. In line with the National Green Tribunal's order of 2015, for instance, from October 2018 onwards diesel vehicles older than 10 years and petrol vehicles older than 15 years shall not be registered in the National Capital Region (NCR), Delhi (NGT 2015; Supreme Court of India 2018). Furthermore, also in Delhi, for the first time Indian authorities are considering a congestion tax during peak hours (Das Gupta 2018).

2.6.8 Russia

Because household vehicle ownership during the Soviet period was systematically restricted by the politics of the time, the focus was then on developing the public transport system. Despite the ongoing motorisation boom in the post-Soviet era, current transport policy once again aims primarily at improving public urban transport. At the same time, however, the Russian government continues to introduce new programmes for supporting both car manufacturers and buyers, thereby stimulating the growth in demand for cars, as well as production figures. Subsidy programmes have been extended, providing favourable interest rates on car loans to motivate customers to buy new cars, for instance by a preferential leasing programme that subsidises the down payment needed at the start of a lease period (AUTOSTAT analytic agency 2015). In turn, an age-based taxation system is in place for imported vehicles: a 30% tax increase is levied on imported vehicles older than one year, and a 35% tax increase on those from three to five years old (UNECE ICT 2017:16).

2.6.9 South Africa

Similarly to the practices of other countries, the import of vehicles is controlled in order to protect the national motor vehicle manufacturing industry. Import duties of up to 36% apply to vehicles up to 20 years old. While taxes on new cars amount to 42%, annual licence fees are inexpensive.

With the aim of supporting more sustainable and greener forms of transport, the government recently launched its Green Transport Strategy for South Africa: (2018–2050). It focuses not only on cars, but also addresses car users, who will be affected in several ways: by scrapping regulations, congestion charges, licence fees based on vehicles' carbon dioxide (CO2) emissions, and mandatory roadworthiness tests.

2.7 Inexpensive Driving

The price of conventional fuels such as petrol or diesel is directly dependent on the price of oil on the world market, which in turn is subject to a variety of influences (e.g. remaining economically exploitable resources, the current worldwide demand for crude oil, and currency volatilities). The final retail prices are also subject to national taxes, some of which vary considerably across countries. In 2016 the percentage tax on petrol, for example, ranged from a low of 2% in Russia, through 18% in the United States, to a high of 58% in Germany; the remaining countries each have values between 37% and 45% (GIZ 2017a). Equivalent percentages for diesel are slightly lower in all countries, except for South Africa, reflecting policy-driven measures. Notwithstanding all national particularities, retail price differences between petrol and diesel are slowly narrowing (Figure 2.9).

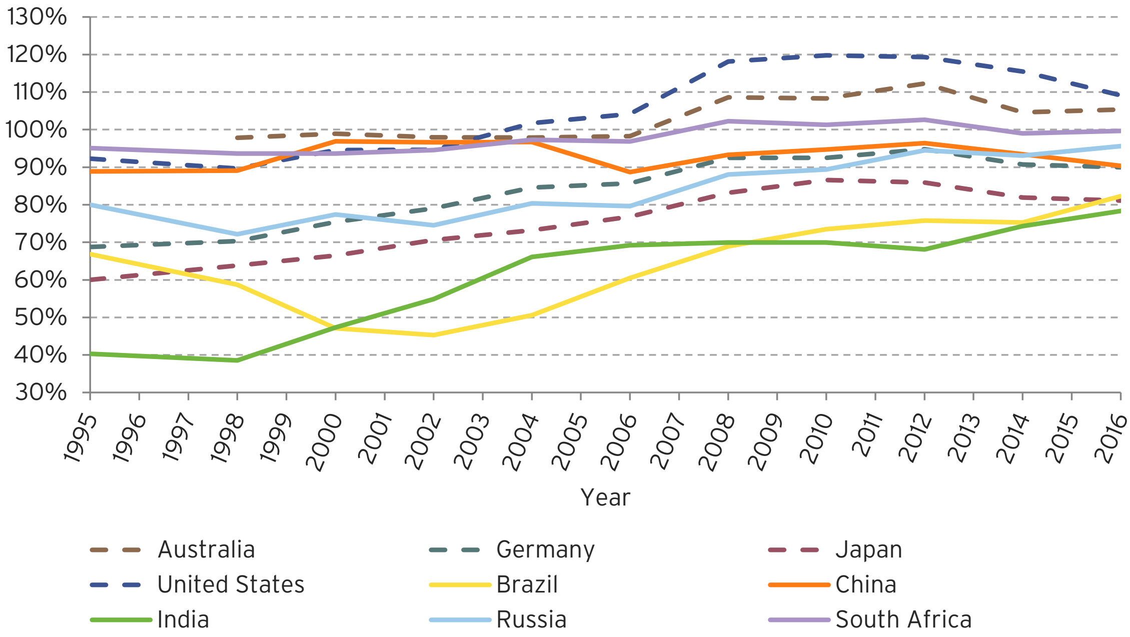


Figure 2.9. Diesel Retail Price as a Percentage of Petrol Retail Price

SOURCE: GIZ (2017a).

The costs of driving a vehicle to a considerable extent determine its actual use. The decisive factor here is how high expenditure on fuel, for example, is in relation to disposable income. Regardless of short-term fluctuations, the OECD countries in particular enjoy comparatively low prices compared to income (Figure 2.10). Over the years, they have followed a path towards lower shares of fuel expenses in relation to income. So far, the BRICS countries have also followed this path, albeit at a significantly higher level.

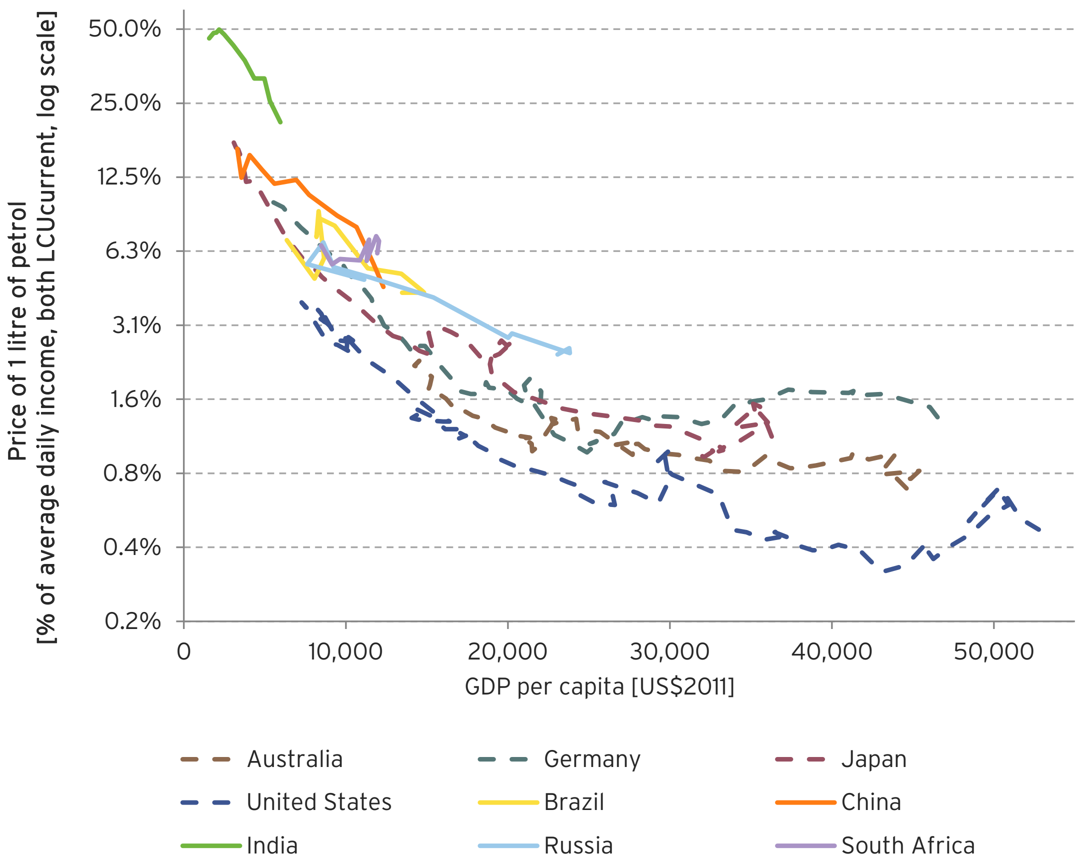


Figure 2.10. Retail Price for Petrol as Share of Average Daily Income (GDP Per Capita)

SOURCE: Fuel prices: until 2009: Ecola et al. (2014), database provided by ifmo. 2010–2016: GIZ (2017a). GDP: until 2009: Ecola et al. (2014), database provided by ifmo. 2010–2016: Bolt et al. (2018a).

2.7.1 Australia

With the beginning of the deregulation of the price of domestically produced oil in 1978, domestic fuel prices started to ever more closely follow trends in the (real) price of imported oil, a process that was completed by about 1985 (BITRE 2012a). Until then, domestic retail prices were less expensive than the equivalent international market prices. Although the percentage share of taxes in the price of petrol stands at a relatively high level of 38% in 2016 (share of fuel tax, own calculation based on GIZ 2017a), expenditure on fuel amounts to only 0.7% of disposable income.

2.7.2 Germany

German retail prices for petrol are the highest of all the study countries, not least because of high taxation, amounting to 58% in 2016 (GIZ 2017a). The equivalent share for diesel was 52%, resulting in a pronounced preference for diesel cars. However, this weakened considerably with the diesel emissions scandal (wherein some German car manufacturers were found to have been designing their diesel engine software to detect when they were being officially tested, and generate a far lower level of harmful emissions during the test than in any real-world driving situation) that came to light in 2014. Despite the high absolute prices, expenditure on fuel in Germany amounts to only 1.24% of disposable income (GIZ 2017a).

2.7.3 Japan

Similarly to Germany, but even more strikingly, in Japan the price of petrol relative to disposable income fell to a remarkably low level of only 1% in 2016 (GIZ 2017a). While the tax rate applied to petrol was still at a comparatively high level of 45% in 2016, taxation of diesel was considerably lower, at only 34% (GIZ 2017a). Notwithstanding the critical view of diesel vehicles in North America and Europe as a result of the emissions scandal, demand for diesel vehicles is rising in Japan.

2.7.4 United States

By international standards, the United States has not only long enjoyed very low absolute prices, but also a very low taxation on both petrol and diesel, with a 2016 rate of 18% and 11% respectively (GIZ 2017a). Correspondingly low is the petrol price relative to disposable income; in 2016 it was only 0.7% (GIZ 2017a).

2.7.5 Brazil

The share of taxes in the petrol price in 2016 was 43%, while that for diesel was only slightly lower at 39% (GIZ 2017). Actual retail prices relative to disposable income, however, are quite high, accounting for about 4% of disposable income in 2016 (GIZ 2017a). Moreover, since 2017, the price of fossil fuels increased considerably as the parastatal oil concern Petrobras linked them to the world market (DW 2018).

After the United States, Brazil is the second largest producer of bioethanol fuel (RFA 2019). Since the late 1970s, there has been a statutory obligation to blend petrol with ethanol. Consequently, flexible-fuel vehicles are widely used; they run not only on blended petrol, but also on hydrated ethanol. Like fossil fuel prices, ethanol prices are subject to seasonal fluctuations.

2.7.6 China

Fuel prices in China are still regulated and subsidised by the government, even if they are adjusted to international prices. As in Brazil, actual retail prices amounted to about 4% of to disposable income in 2016 (GIZ 2017a), although the share of fuel tax is slightly lower (40% for petrol, 28% for diesel). Prices are expected to decline as the government is committed to promote both electric vehicles and the domestic production and consumption of bioethanol; China already ranks third behind the United States and Brazil in bioethanol production, but at a significantly lower level (RFA 2019).

2.7.7 India

While diesel is the most important fuel for public transport, petrol is the primary fuel used by cars and most scooters and motorcycles (Sundria & Chakraborty 2018). Until 2010, petrol pricing was regulated by the government; diesel is still subsidised (Verma et al. 2017), but the government has started to reduce subsidies to reduce pressure on the national budget. The share of taxes amounts to 40% for petrol and 28% for diesel. Since mid-2017, retail prices have been subject to daily revisions, aligning them to global oil prices (IISD 2017). Given the low average income levels, actual retail prices relative to disposable income are the highest among the study countries, still running at 20.9% in 2016 (GIZ 2017a). This is, however, a tremendous reduction compared to the figure of around 50% in the early 2000s.

2.7.8 Russia

In terms of actual retail prices as a proportion of disposable income, Russia comes the closest to OECD levels at 2.4% in 2016 (GIZ 2017a). However, while petrol and diesel taxes are low, state subsidies are concentrated mainly on natural gas and electricity (GIZ 2017, IEA 2014).

2.7.9 South Africa

Dating back to the 1920s, South Africa has a long tradition of liquefying domestic coal into fuel, and this gained importance during the apartheid era as a result of very significant sanctions imposed by the rest of the world. The daily production of Sasol, the major producer of synthetic fuel, serves 30% of South Africa's transport fuel needs (Schutze 2008). After international sanctions were lifted, the government introduced subsidies on crude oil; in 2016, the tax shares for petrol and diesel were about 37% and 36% respectively. An additional carbon tax, to be added to petrol and diesel prices, is expected in mid-2019 (The South African 2019).

Actual retail prices relative to disposable income are quite high, accounting for about 6.1% in 2016 (GIZ 2017a). In the long run, driving costs are expected to increase owing to declining production from coal.

2.8 Car Culture

As stated in Ecola et al. 2014 and mentioned above, car culture is probably the most subjective factor considered. In order to capture trends in the study countries, we conducted an online survey of experts (see subsection 1.3.1, ‘Selecting Indicators and Data’). Generally, car culture was scored positively for all countries. Perhaps surprisingly, car culture in the BRICS countries falls within a similar range to that found in the four OECD countries. While the absolute figures should not be made too much of, one clear observation is that the importance of car culture is expected to increase in the BRICS countries, whereas it is stagnating (Japan, United States) or declining (Australia, Germany) in the OECD countries (Figure 2.11). A few observations are provided below.

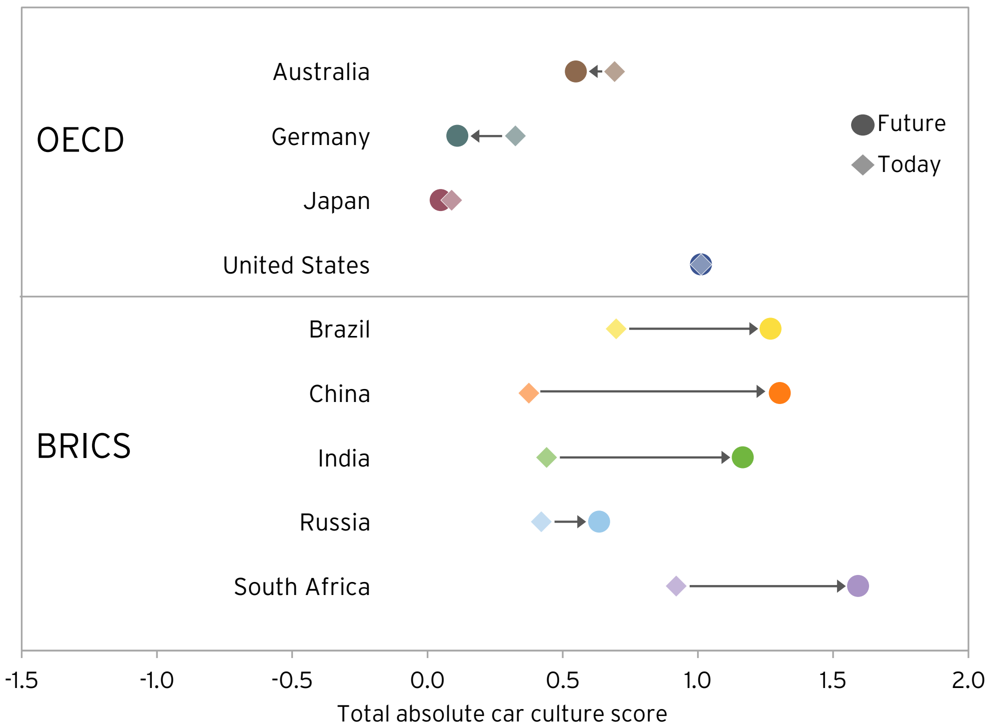


Figure 2.11. Ranking of the Importance of the Factor Car Culture and its Trends

SOURCE: Own survey.

2.8.1 OECD countries

In the OECD countries the positive valuation of the factor car culture for the United States sticks out, with Australia following second. However, only two persons responded from those countries. In Australia, Japan and the United States, the dimension of car culture (see Section 1.3.2) 'autonomy by automobility' plays the largest role, whereas in Germany the dimension 'personal attitudes' is the most prominent. 'Privacy' and 'status symbol' are also relevant dimensions, and here the United States stands out again. 'Cars in popular culture' is relevant only for Australia and the United States.

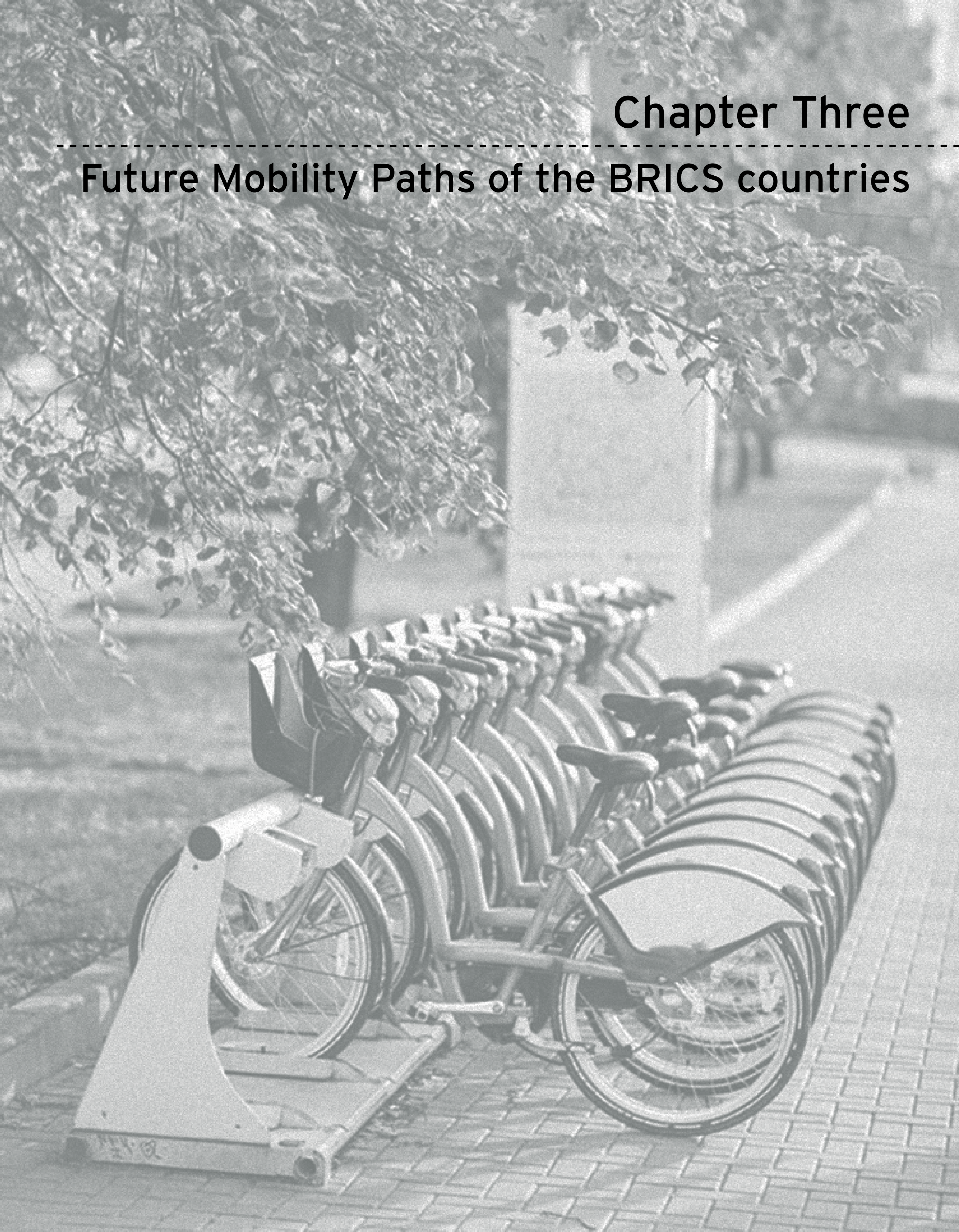
2.8.2 BRICS countries

For the BRICS countries, the most interesting observation is that the dimension 'status symbol' ranks the highest in all countries. This is followed by 'popular culture' (India & South Africa), 'autonomy' (South Africa), 'privacy' (Brazil), 'personal attitudes' (Brazil & China) and 'cars as living space' (Russia).

One may conclude that cars in emerging economies are more an expression of wealth and status than in rich economies, where the ownership of particular cars is no longer an expression of exceptional wealth. Anecdotally, the pride of owning a car in the OECD countries in the 1950s and 1960s is still remembered, and at that date a car, even in those countries, absorbed a significant portion of ordinary citizens' income. Today, a vast number of citizens can afford costly new vehicles in the OECD countries, and thus the means of expressing one's wealth has refocused on other more modern status symbols. In emerging economies, a similar development can be expected.

Chapter Three

Future Mobility Paths of the BRICS countries



3.1 Summary of the Automobility Scores

As described in section 1.3, 'The Study Methodology', we firstly analysed the position of each of the four OECD countries regarding each factor. The flag game provided a vivid way to discuss the possible development pathways in the study countries at the expert workshop. The assessments were informed by the statistical findings presented in Chapter Two, 'Factor Findings for the Study Countries' combined with expert statements. Secondly, each factor was weighted to reflect its influence on VKT and motorisation separately (see Table 3.1). Table 3.2 summarises all the individual factors for the two reference points of GDP per capita. The overall automobility scores for VKT and motorisation were calculated as a weighted mean using the weighting factors in Table 3.1.

Table 3.1 shows the eight factors, their classification as exogenous or transport policy factors, and the respective weights agreed upon during the workshop. Individual weights range from 1.4 to 2.9. With regard to the motorisation, the factor lack of alternatives reaches the highest weight. However, the spread (the range) of motorisation factor weights is smaller than for the car usage factors.

With regard to car usage (VKT), the factors spatial dispersion and lack of alternatives are weighted the highest. Domestic car industry and car culture on the other hand are weighted the lowest. These two factors do play a role in motorisation, but less so in car usage.

Table 3.1. Factors for Assessing Vehicle-Kilometres Travelled and Motorisation, its Categorisation and the Factor Weights

Factor	Factor type	Factor weight (impact: 1 = low, 2 = medium, 3 = strong)	
		for car ownership	for car usage (VKT)
Active population	exogenous	2,0	2,3
Spatial dispersion	exogenous	2,6	2,9
Domestic car industry	exogenous	2,1	1,4
Car culture	exogenous	2,4	1,8
Car infrastructure	transport policy	2,3	2,6
Lack of alternatives	transport policy	2,7	2,8
Pro-car policies	transport policy	2,4	2,3
Inexpensive driving	transport policy	1,7	2,3

NOTE: The highest scores above 2.5 are highlighted in bold.

In our discussions, it was apparent that future levels of motorisation will be determined significantly by policy decisions and technological developments. On the policy side, countries are reacting using regulatory means to external challenges, which include congestion, competition for space, and climate change. On the technological side, new developments such as electrification, digitalisation and automation have the potential to reshape mobility in the future. These two aspects – policy decisions and technological developments – are likely to have a profound effect on motorisation. However, we are confident that the demand for individual mobility will correspond with economic development and individual wealth. Thus, while we believe that the VKT figures derived in this project do represent the individual demand for mobility, we cannot be certain as to the kinds of technologies that will be used to satisfy this demand in the future. For example, the implementation of shared mobility services, both electrified and modular, will eventually diminish the total number of cars needed to satisfy the mobility needs envisioned.

The pattern of the automobility scores reveals two distinct groups of countries: those clearly in favour of automobility and those less favourable to automobility (Table 3.2). The United States and Australia both have positive automobility scores, and of these two the United States clearly stands out with high positive scores for both car usage (VKT) and motorisation. Germany and Japan, on the other hand, both have negative automobility scores. The BRICS countries are also divided into those with positive and those with negative values, with Brazil and South Africa clearly in the positive group, while India and China are in the negative category. Russia takes a more neutral position somewhere in between the two, with positive values close to zero. Another observation is that for all BRICS countries except South Africa, the automobility score for car usage (VKT) is below that for car ownership. It may indicate that factors are less favourable for the use of cars in comparison to their effect on the ownership of cars.

Table 3.2. Country Factor Scores for Each Individual Factor and the Overall Weighted Automobility Score for Motorisation and Vehicle-Kilometres Travelled per Factor

Country	Year when GDP reaches 10,000 and 35,000 US$ per capita	Active population	Spatial dispersion	Domestic car industry	Car infrastructure	Lack of alternatives	Pro-car policies	Inexpensive driving	Car culture	Overall automobility score - car ownership	Overall automobility score - vehicle kilometres travel
Australia	1934	0,1	-0,8	-0,8	-1,2	0,1	1,2	0,5	0,4	**0,39**	**0,43**
	2000	0,9	1,8	-0,1	1,4	0,9	0,6	0,9	0,3		
Germany	1955	-0,5	-1,3	0,9	-0,2	-0,9	0,1	-1	0,2	**-0,16**	**-0,24**
	1998	0,4	-0,5	1,8	1,4	-1,5	-0,5	-0,3	-0,1		
Japan	1967	0,4	-1,8	0,7	-1,3	-0,8	0,5	-1,1	0	**-0,42**	**-0,51**
	2004	0,0	-0,9	1,6	0	-1,5	-1,2	-0,2	-0,3		
United States	1939	0,4	-0,8	1,4	-1,1	0,1	1,8	1,3	1,6	**0,89**	**0,87**
	1988	0,9	1,7	0,4	1,8	1,5	0,9	1,7	0,9		
Brazil	1986	0,9	-0,2	0,7	-0,5	-0,1	0,9	-1	0,3	**0,28**	**0,20**
	2058	1,1	0,3	1,3	0,2	-0,4	0,6	-0,6	0,9		
China	2011	1,3	-1,7	0,4	-0,7	-0,5	-0,1	-1	-0,3	**-0,33**	**-0,39**
	2033	1,5	-1	1	0	-1,7	-1,6	-0,6	0,6		
India	2027	0,6	-1,7	-0,2	-1,4	-0,1	0,3	-1	-0,5	**-0,39**	**-0,44**
	2066	1,5	-0,9	0,7	-0,4	-1,5	-0,6	-0,6	0,2		
Russia	1990	0,4	-1	-0,2	-0,1	-0,4	1,2	0,3	0,4	**0,08**	**0,04**
	2026	1,0	-0,3	1,1	0,2	-1,5	0,5	-0,2	0,6		
South Africa	2003	-0,6	1,9	-0,8	0,2	1,3	0,9	0,9	0,8	**0,60**	**0,62**
	2058	-0,3	1,4	-0,2	0,8	0,4	0,5	0,1	1,4		

*NOTE : * For this project we consider 1990, the end of the Soviet Union, as the starting point. GDP per capita was 20,000 US$2011 in 1990. The final automobility score combines each factor score for the beginning of the motorisation phase and the reaching of the saturation point with the factor weights and builds then an average automobility score.*

We further processed the individual scores to visualise the magnitude of influence for each country (Figure 3.1 and Figure 3.2). We hereby followed the same formula than in the previous study, which takes into account the factor scores, the delta between the automobility scores for the saturation point and for the beginning of motorisation and the respective factor weights[6]. The formula takes both the absolute automobility scores of the factors and the trend of development of the automobility scores into account. Its result is an expression of relative importance of the factors for each country.

For Australia, nearly all factors point in favour of automobility, with spatial dispersion having the greatest influence. For the United States, all factors are in favour of automobility, with spatial dispersion, inexpensive driving and lack of alternatives scoring particularly high values. On the other side lie Germany and Japan. In both countries, the factors spatial dispersion and lack of alternatives have a strong dampening influence on automobility. This is combined with other negative scores. Only the German car infrastructure and the German and Japanese domestic car industry significantly counter the other scores. Considering that spatial dispersion, car infrastructure and lack of alternatives have the highest weights for deriving the overall automobility score for VKT (Table 3.1), this visualisation illustrates very well the distinction between the United States and Australia on the one hand, and Germany and Japan on the other.

When looking at the results for the BRICS countries (Figure 3.2), the importance of spatial dispersion and lack of alternatives becomes clear once more. While China, India, and Russia have a spatial dispersion factor that is less in favour of automobility, Brazil's spatial dispersion, and even more so South Africa's, favours automobility. This corresponds well with the observations in Chapter Two, 'Factor Findings for the Study Countries'. Although the five countries are very different from each other, the spatial setting of urbanisation, urban density and structures within them, as well as their countrywide characteristics, strongly influence the automobility of them all. Likewise the highly negative score of the important factor lack of alternatives in China, India and Russia in particular indicates that they are providing, or are well prepared to provide, other means than the individual car to satisfy mobility needs; only South Africa scores positively. Domestic car industry is an important factor for all countries except South Africa. This, together with the factors car culture and pro-car policies (for Brazil, Russia and South Africa) works in favour of automobility. In China, and to some extent in India, it is expected that policy decisions will dampen the development of automobility, as the negative magnitudes for pro-car policies show. Lastly, the degree of active population has a strong positive influence on automobility for all BRICS countries except South Africa.

[6] The formula is (ASmot + ASsat) + ((ASsat – Asmot)/2) /2 * factor weight.

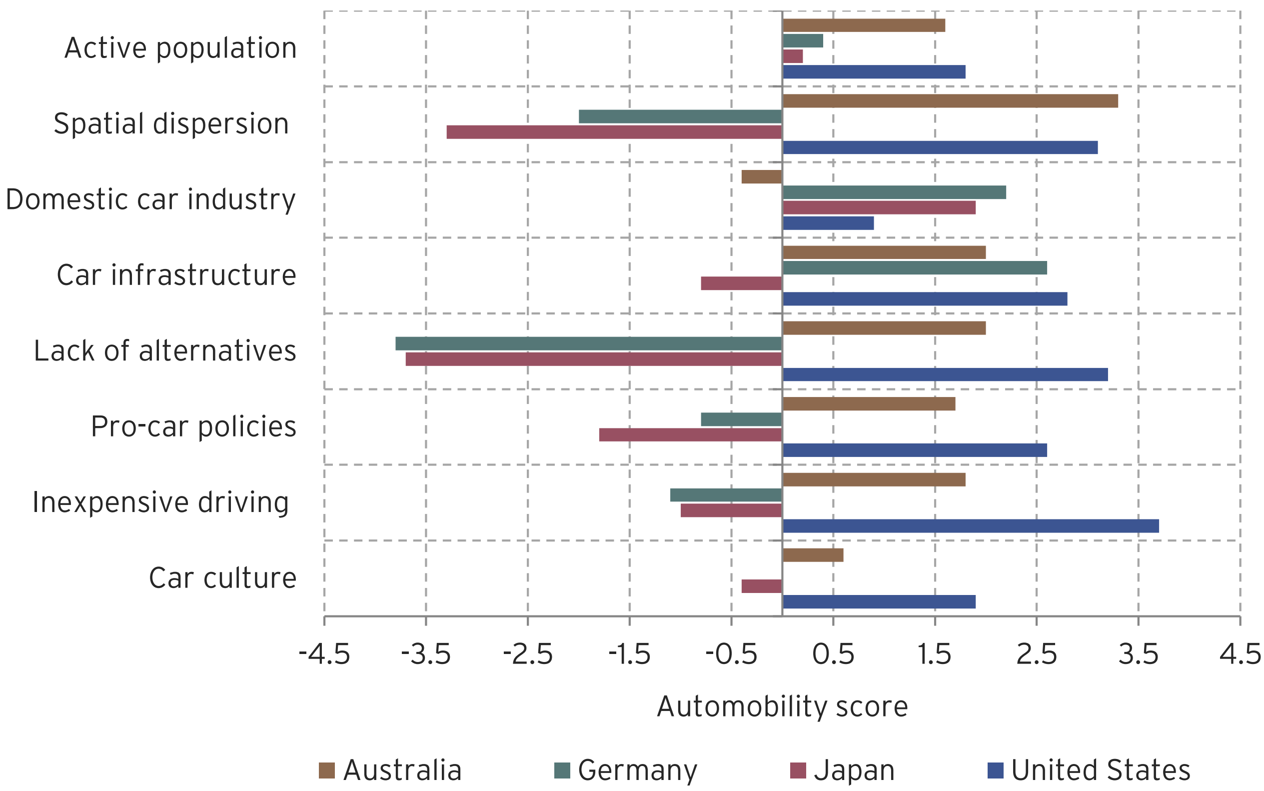


Figure 3.1. Magnitude of Influence of Each Factor for the OECD Countries

NOTE: A negative value indicates less in favour of automobility; a positive value indicates more in favour of automobility.

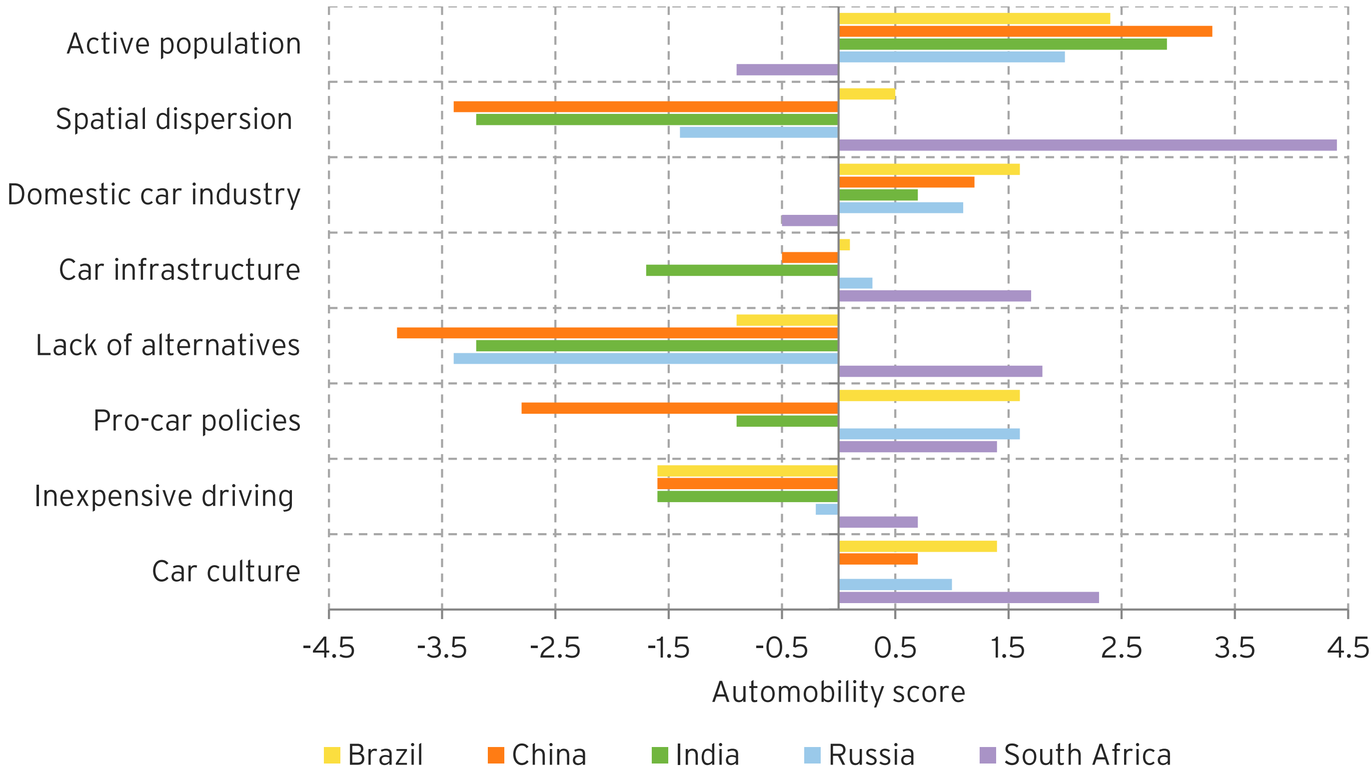


Figure 3.2. Magnitude of Influence of Each Factor for the BRICS Countries

NOTE: A negative value indicates less in favour of automobility; a positive value indicates more in favour of automobility.

In Ecola et al. (2014), an analysis was also undertaken of how the factors have developed, or will develop over time, from the beginning of motorisation to approaching the saturation points. For this analysis, they were separated into 'exogenous' factors and 'transport policy' factors. Exogenous factors are those which are determined by externalities (active population, spatial dispersion, domestic car industry and car culture), whereas transport policy factors are those that can be influenced, at least in the long term, by policy decisions (car infrastructure, lack of alternatives, pro-car policies and inexpensive driving). The comparison of the results reflects several recent trends (Figure 3.3).

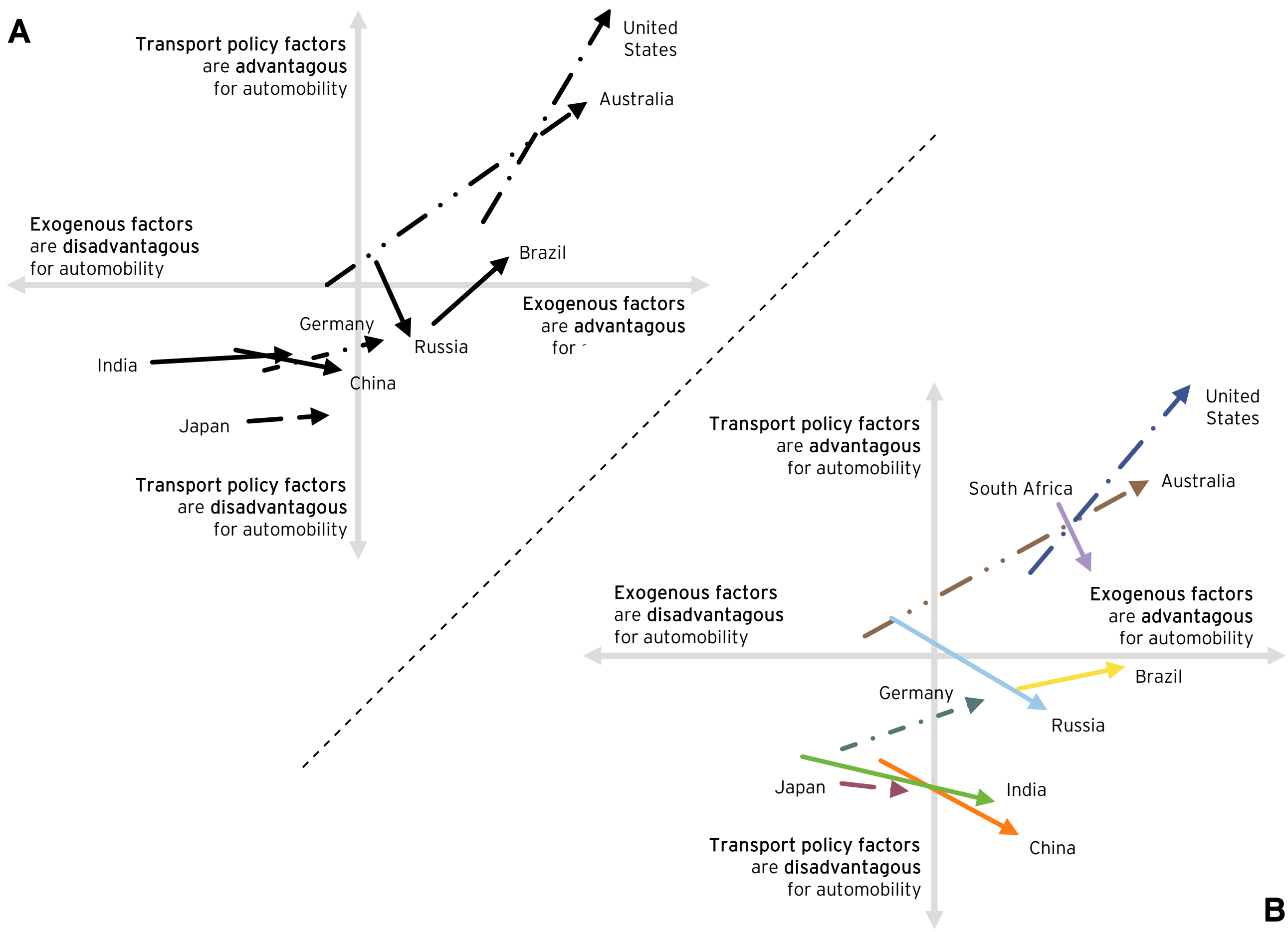


Figure 3.3. Development of Automobility Scores Over Time – A: Results from Ecola et al. (2014);
B: Update from this study

SOURCE: A: Ecola et al. (2014).

NOTE: South Africa was not included in Ecola et al. (2014).

For the BRICS countries, the perceptions of the exogenous factors in particular are trending to favour automobility more today than five years ago. However, at the same time, the transport policy factors are, for the BRICS countries (with the exception of Brazil), displaying a present-day trend that we expect to work less in favour of automobility. This is a very plausible result, considering evidence in the BRICS countries of recent trends in new mobility services, digitalisation and automation on the one hand, and the increasing competition for space and infrastructure challenges in the growing urban agglomerations on the other hand. While the decades following 1990 were characterised by market liberalisation and conditions that facilitated unimpeded growth, recent years have revealed limits to growth and a resurgence of policies focussing on national regulations. Since the results from Ecola et al. (2014), the BRICS countries have, overall, moved more towards the lower right quadrant in the figure. Slight changes in the arrows of the OECD countries are due to the updates of GDP and automobility figures.

3.2 Derivation of Saturation Levels for the BRICS Countries

One goal of this study, building on the results from Ecola et al. (2014), is to create future projections of saturation levels with regard to VKT per capita. As we have remarked, the development of VKT in the OECD countries has followed an S-shaped curve. The relationship of GDP and spatial aspects with car usage, has been prominently analysed by Dargay et al. (1999, 2007). Dargay argues that the use of a Gompertz function best fits the S-shaped development curve of VKT.

We therefore repeated the Gompertz calculation with the updated figures on GDP per capita and automobility. While the Gompertz function focuses on the relationship between GDP per capita and VKT, its validity is also evident when plotting the result using an x-axis that represents time (see Figure 1.2).

The Gompertz model fits well with the historic trends in OECD countries. However, especially during the last five years, the development of VKT was non-uniform. In the United States a sharp decline in VKT can be observed, tracking the financial crisis of 2008/2009, and a low level of VKT was then seen until 2014. In 2015 and 2016 VKT resurged to regain its 2000 level. Its further shape cannot be predicted, but it is likely that the United States has reached saturation in the 14,000–15,000 VKT range. Similarly Australia has reached VKT saturation, at a little below 10,000 km per capita. Here too, a decline simultaneous with the financial crisis can be observed, but the resurgence in 2015 is much smaller. In Japan, the VKT started to level off in 2000 and generally declined thereafter, despite a small upturn in 2014. We would argue from the visualisation that Japan has also reached a saturation level of VKT per capita, not least because of its demographic development. However, the Gompertz function for Japan indicates a further growth of VKT. This is due mostly to an economic crisis in the early 1980s, followed by a period of GDP growth per capita from 1986 to 1996, after which the GDP growth was again sluggish. The VKT per capita increased over this entire period of time until 2000. As a result of the steep VKT increase in the 1990s, the Gompertz function predicts a VKT saturation in the range of 6,000 km per capita, but this is something which we deem unlikely. Considering the developments in recent years, combined with the spatial structure and the limitations inherent in an island, we assume that saturation for Japan is more likely to be in the order of 4,500 km travelled annually per capita. Germany, in contrast to the other countries, has not undergone any decline in VKT in the aftermath of the financial crisis of 2008. On the contrary, VKT there continues to rise, both with GDP (Figure 1.1) and over time (Figure 1.2). The Gompertz function represents the development path very well in Germany's case, and a saturation in the region of 8,400 km per capita can be expected.

As in Ecola et al. (2014) we now applied a simple regression analysis, using the VKT saturation levels from the Gompertz function and the combined automobility score (Table 3.2) to derive the probable VKT saturation levels for the BRICS countries (Figure 3.4). The saturation levels of VKT of this study update are generally lower than those of the earlier study. This corresponds well with the trends expressed in Figure 3.3, indicating an increasing level of policy intervention in the sphere of automobility in India and China.

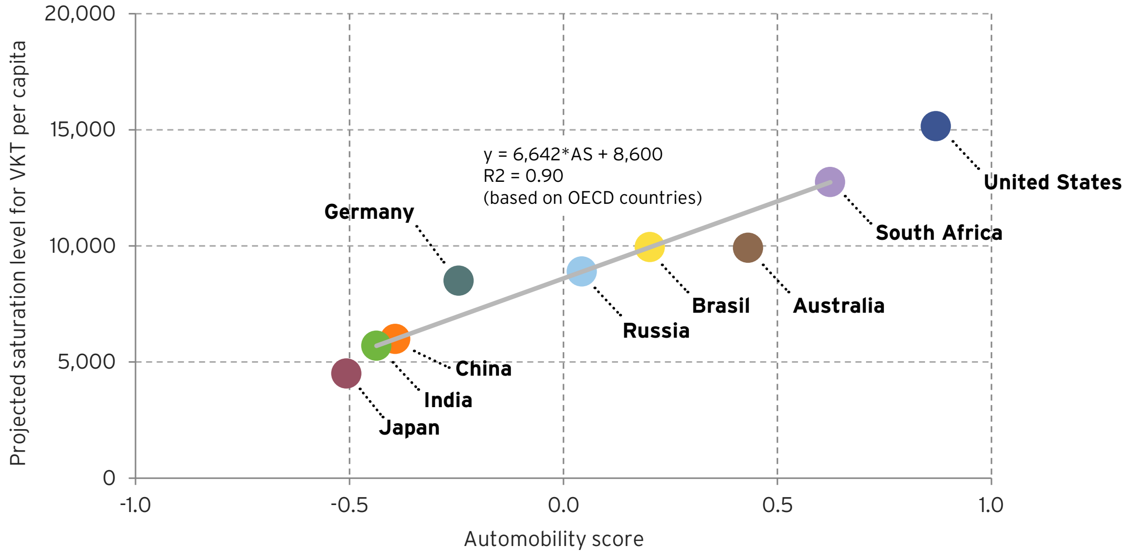


Figure 3.4. Linear Regression of VKT Saturation Levels and Automobility Scores – Plot of VKT Saturations for the BRICS Countries

Table 3.3. Resulting VKT Saturation Levels from the Gompertz Function (Australia, Germany, Japan and United States) and the Linear Regression over Automobility Scores (Brazil, China, India, Russia and South Africa)

Country	VKT Saturation 2014 (km) (Ecola et al 2014)	VKT Saturation according to this study update (km)	Delta between Ecola et al 2014 and this study update
Australia	10,800	9,900	-8,3%
Germany	9,700	8,400	-13,4%
Japan	6,400	4,500	-29,7%
United States	16,300	15,100	-7,4%
Brazil	11,300	9,900	-12,4%
China	7,800	6,000	-23,1%
India	7,000	5,700	-18,6%
Russia	10,200	8,900	-12,7%
South Africa	not included	12,700	NA

As stated in section 3.1 above, we consider VKT to represent the demand for mobility that comes with economic development and individual wealth, but this projected demand in the BRICS countries might not translate into motorisation in a similar way as happened in the OECD countries – it might be satisfied by other mobility modes and services. In forming projections of motorisation, we thus decided to take the approach of applying a range of VKT per car that can be observed in the OECD countries. For this, we looked at the development point of 35,000 US$2011 GDP per capita, when car usage started to saturate. At this average level of personal wealth, the OECD countries displayed VKT levels of 7,800 km per year (Japan), 14,900 km per year (Germany), 16,000 km per year (Australia) and 17,100 km per year (United States). Since Japan is something of a special case, being an island state and characterised by very dense urban agglomerations, we laid aside its level and chose the figures for Germany and the United States as minimum and maximum reference points respectively. The BRICS countries are all continental countries with large surface areas, and thus in spatial terms are characterised by much more widely spread development than is found in Japan.

The number of cars per capita was then computed by first calculating the total number of cars, using the kilometres per car figures of Germany and the United States, and then back-calculating the number of cars per capita. Applying those minimum and maximum figures results in potential long-term motorisation, in terms of cars per 1,000 population, of between 280 (India) and 730 (South Africa) (Table 3.4)

Table 3.4. VKT and Derivation of Probable Number of Cars Per Capita at the 35,000 $US\$_{2011}$ GDP Per Capita Level

Country	Figures at the point when countries reach 35,000 $US\$_{2011}$ GDP per capita			
	Reference year	**VKT per capita**	**Cars per 1,000 population**	**km per car**
Australia	2000	9,700	600	16,000
Germany	1998	6,700	450	14,900
Japan	2004	4,100	530	7,800
United States	1988	12,400	720	17,100
Brazil	2058	8,500	490-570	14,900-17,100
China	2033	5,100	290-350	14,900-17,100
India	2066	4,800	280-330	14,900-17,100
Russia	2026	7,600	440-510	14,900-17,100
South Africa	2058	10,900	630-730	14,900-17,100

NOTE: The delta of minimum and maximum km per car (14,900 and 17100 km) is 13 %. The delta of the projected cars per 1,000 population differs due to rounding effects.

Chapter Four

The Future Role of New Mobility Services and Technologies

4.1 New Mobility Services

High expectations surround new mobility services. Especially since the appearance of mobile devices in the early 2000s, new service offerings have surged in many markets. Among new mobility services that can be identified are: station-based car sharing, free-floating car and bicycle sharing, ride hailing and car pooling. While the car-sharing models are essentially short-term rentals with or without fixed stations, ride hailing refers to the trip-based profitable sale of a transport service in a (private) car, not unlike a traditional taxi. Car pooling refers to the not-for-profit offering of empty seats in a trip that would have taken place anyway.

Some of those offerings compete with established services, such as taxis, for the same trips – and in some cases also with public transport. This has led several governments to start regulating new mobility services or even to try to prevent their market entry. Furthermore, it still remains unknown today whether those offerings would increase or decrease the number of cars on the road and the total VKT. This probably depends to a large extent on the amount and type of guiding regulation accompanying the introduction of the services.

Today the market share of new mobility services is very low, in contrast to the amount of public attention that is given to those services. In the United States, ride hailing (e.g. taxi, Uber, Lyft) makes up only 0.5% of total trips, and car sharing a further 0.2% (according to the 2017 National Household Travel Survey, own analysis). In Germany, ride hailing represents 0.2% and car sharing 0.1% of all trips (according to the 2017 Mobility in Germany data, own analysis). In Shanghai, ride hailing has won over 7% of all trips, thus indicating a higher relevance of this kind of service in some urban agglomerations of emerging economies.

Two possible direct impacts of new mobility services can be distinguished (Figure 4.1): first, new mobility services will reduce the use of other modes, whether private car or public transport. Second, some people might either get rid of their own car or forgo the purchase of a car for themselves. If the second were to happen, this would also indirectly affect the modal choice. However, whether or not new mobility services will have a profound effect on motorisation is heavily debated.

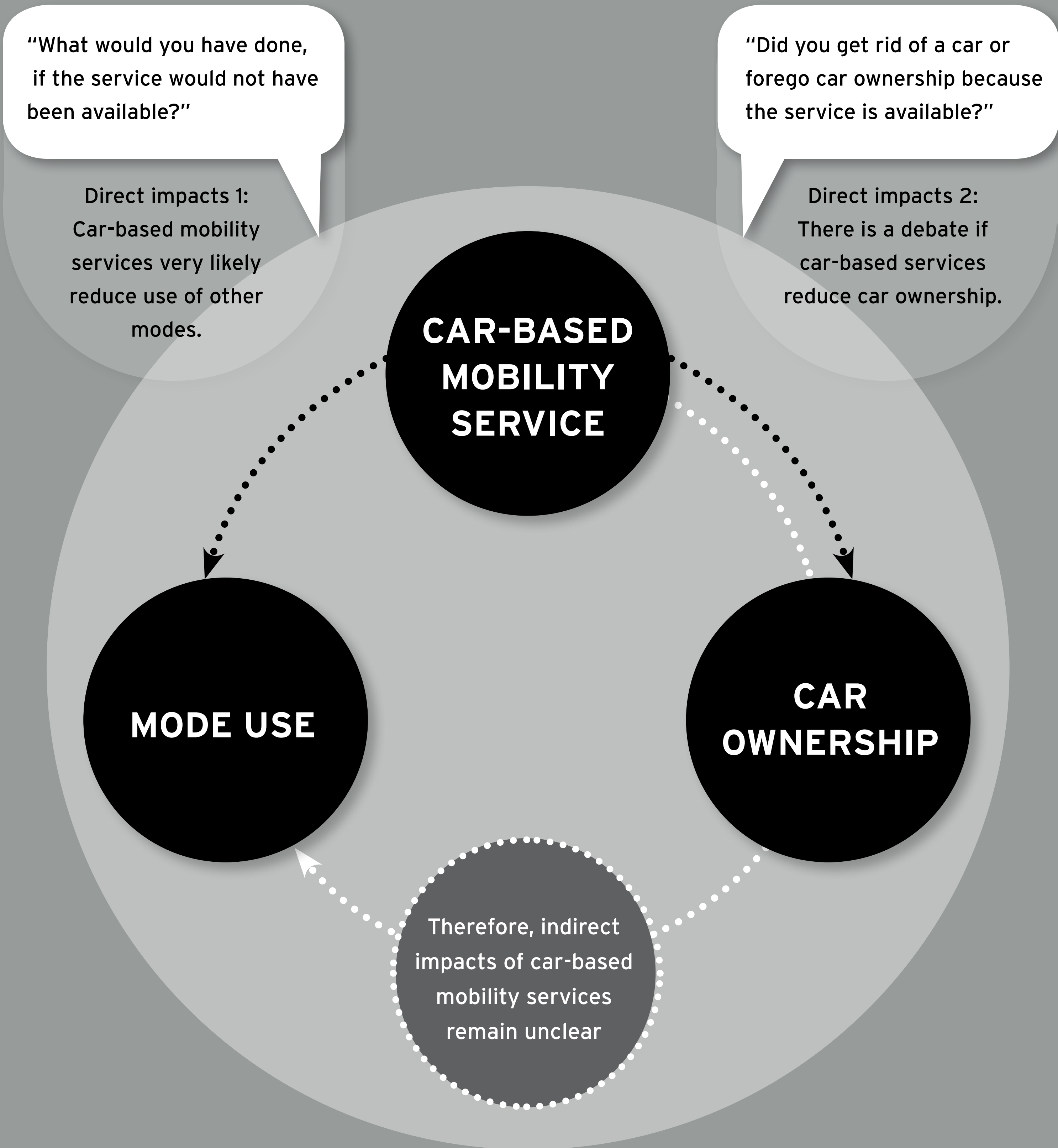


Figure 4.1. Possible Effects of New Mobility Services

The degree of regulation, particularly of ride hailing as a profitable service using private cars, differs strongly in each individual country. For example, while in Germany and Japan, Uber-type services are treated similarly to taxi services, in the United States and Great Britain, Uber is less regulated and is effectively a competitor to the traditional taxi. Brazil and South Africa tend to follow the United States' template; in China, India and Russia, on the other hand, Uber-type ride-hailing services seem to be more regulated.

4.1.1 Australia

Australia has seen station-based car sharing since 2003, mostly in the urban agglomerations of Sydney and Melbourne. More recently, free-floating car sharing has entered the market. From 2015, Uber and other ride-hailing services have entered the market and undergone rapid growth. Those services run parallel to the taxi, but are less regulated.

4.1.2 Germany

Germany has a relatively long history (dating back to the late 1980s) of station-based car sharing. In 2009 free-floating car sharing was introduced to larger cities, and is now growing significantly. Uber-type ride-hailing services are strongly regulated and treated in a similar manner to taxis. Their economic advantage is thus small, and their future market share unclear. Car-pooling services also have a long history, particularly as a means of long-distance travel. Formerly privately organised not-for-profit services (whereby drivers and passengers who are willing to travel together between cities, and share the cost of the journey, find each other) have been commercialised by French BlaBlaCar.

4.1.3 Japan

In Japan, station-based car sharing has existed since 2000 and is still growing. There is no free-floating car sharing. Ride-hailing services are treated similarly to taxis and have practically no market relevance.

4.1.4 United States

Station-based car sharing emerged in the United States in the 1990s. In 2009, free-floating car sharing started up in larger cities. Both services are growing. In 2008, Uber-type ride-hailing services also entered the market. Those are regulated in some cases, on a city level; however, no national regulatory approach is in place, and ride-hailing services compete successfully with a taxi system of sometimes poor quality. In some areas, a strong decline in public transport use owing to new ride-hailing services has been reported.

4.1.5 Brazil

Car sharing in Brazil is a new offering that started in around 2015. Uber-type ride-hailing services are entering the market and are competing with the taxi business. Today it remains unclear which path Brazil is proceeding along. However, a declining use of public transport as a consequence of new mobility services and with it a declining revenue is putting further pressure on public transport infrastructure.

4.1.6 China

The first station-based car sharing services in China appeared in the 1990s. More recently they have seen robust growth. Free-floating car sharing is very young, and has, as yet, low market penetration. Ride hailing is encouraged in many cities in China, and Uber-type services are regulated in a similar manner to taxi services.

4.1.7 India

In India, station-based car sharing has existed since 2000, and it is growing; free-floating car sharing, on the other hand, does not exist in this country. Uber-type ride-hailing services entered the market on multiple platforms in 2000. Their offerings are growing, and they are regulated much like taxis.

4.1.8 Russia

Russia has had station-based car sharing since 2000, and more recently some free-floating car-sharing offerings have begun to emerge. In 2012, Uber-type ride hailing also emerged on multiple platforms and is growing rapidly. Such services are regulated similarly to taxi services. Car pooling has been commercialised by the French company BlaBlaCar, and is growing.

4.1.9 South Africa

Since 2015 there have been some station-based car-sharing services in South Africa, but they are very few in number. As early as 2013, Uber-type ride hailing had entered the market, and it has undergone steady growth since then. Additionally, South Africa has a strong informal public transport sector that lies somewhere between public transport and new mobility services organised by the free market.

4.2 Expert Judgement on New Mobility Services

Similarly to the flag game exercise, we asked the experts during the expert workshop, to make a judgement, from today's viewpoint, as to whether they think that new mobility services will increase or reduce the use of private motorised modes, and of non-car modes in each study country. The year for which they were asked to form their opinions was 2050. Acknowledging that such judgements are bound to be subjective, and can be no more than a snapshot, the results are nevertheless interesting enough to be shared here (Figure 4.2).

For Germany, the United States, Brazil and South Africa, the experts expect that new services will more strongly reduce non-car modes than they will diminish use of the private car. Only in India do the experts assume that new mobility services will complement public non-car modes (i.e. increase their share). The countries seeing the strongest (negative) effect on private car use are Japan, China and India. This judgement corresponds with the findings in section 4.1 as to whether countries are expected to regulate or not regulate the market for new mobility services.

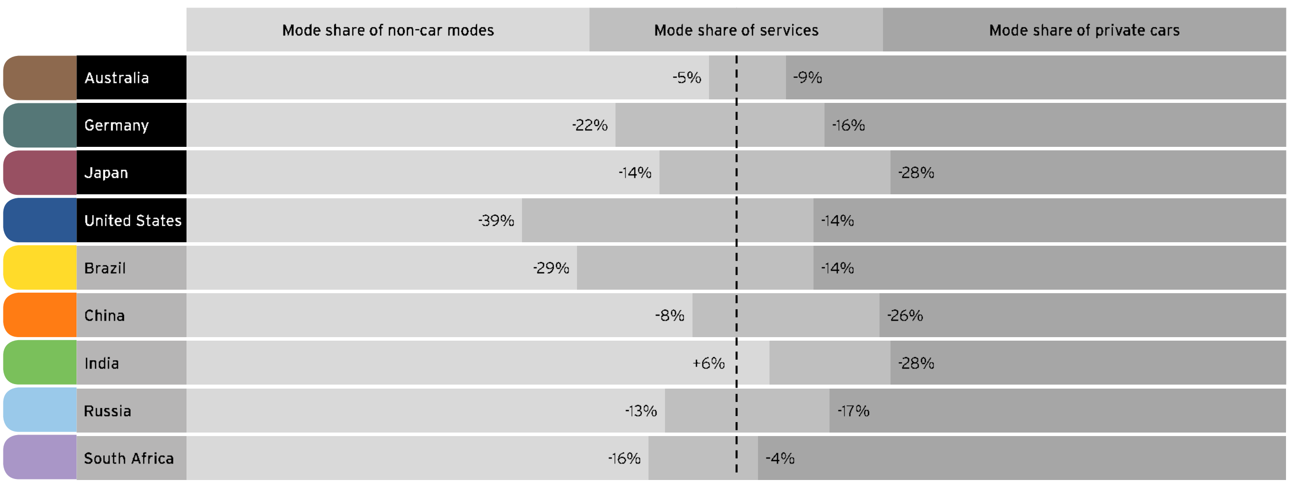


Figure 4.2. Expected Effect of New Mobility Services on Mode Share of Trips in 2050

NOTE: The centreline represents today's mode share in the respective country.

4.3 Domestic Energy

In the former project, the existence of domestic oil was considered as a proxy for VKT. The existence of domestic oil may encourage consumption in order to foster domestic industries (Ecola et al. 2014). In this update we removed this factor from the automobility score, but consider it to be important when it comes to the implementation of new alternative technologies. The reasons for this are twofold: first, we assume that in open international markets, oil is freely traded and its price is thus a question of supply and demand. The origin of the oil resources is thus secondary. Second, we assume, however, that undesirable dependence on foreign resources might turn out to be an incentive for developing technologies to reduce this dependency. For this reason we included both domestic oil reserves (Figure 4.3) and domestic gas reserves (Figure 4.4) as indicators that foster or hinder the development of new alternative propulsion systems.

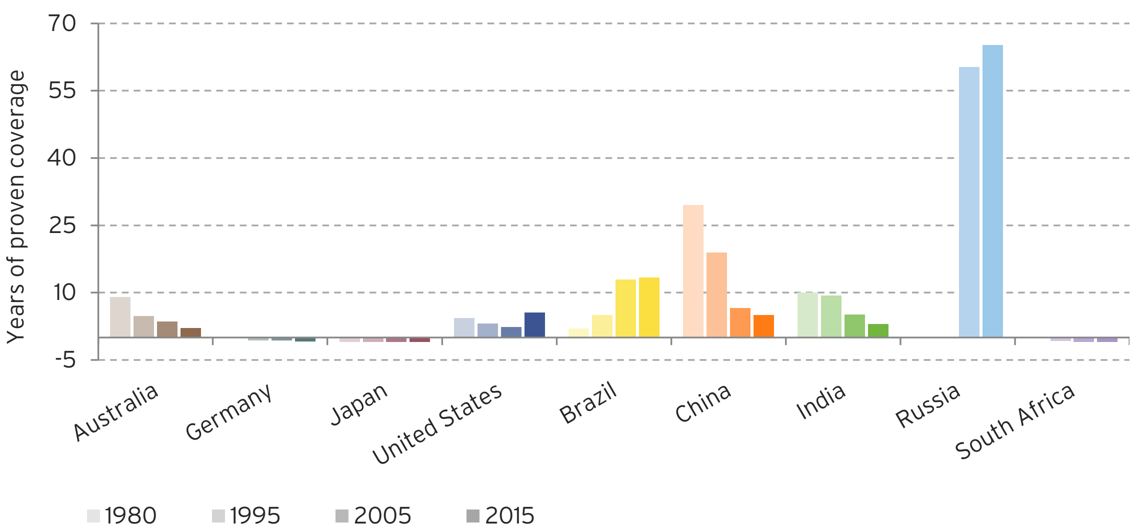


Figure 4.3. Proven Domestic Petroleum Reserves Divided by Annual Domestic Oil Consumption to Show Remaining Years of Proven Capacity

SOURCE: EIA (2018a).

NOTE: A negative value means that annual domestic oil consumption exceeds proven reserves and indicates a high import dependency.

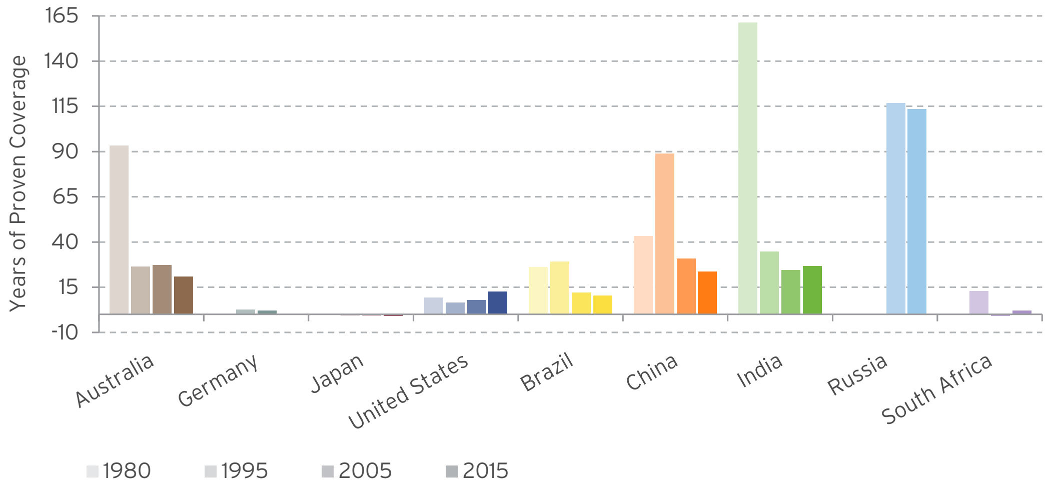


Figure 4.4. Proven Domestic Gas Reserves Divided by Annual Domestic Gas Consumption to Show Remaining Years of Proven Capacity

SSOURCE: EIA (2018b).

NOTE: A negative value means that annual domestic gas consumption exceeds proven reserves and indicates a high import dependency.

4.3.1 Australia

Australia is neither a large oil- and gas-producing country, nor a large consumer of oil and gas in the international context. However, while it does have some domestic oil reserves, Australia has notable domestic gas reserves (the largest proven gas reserves compared to its consumption of the four OECD countries). Gas may thus be one option as a fuel resource, whereas with regard to oil, Australia will become import-dependent.

4.3.2 Germany

Germany is dependent on oil and gas imports. Its domestic reserves are very limited compared to consumption levels. Germany thus has strong incentives to develop alternative propulsion technologies.

4.3.3 Japan

Japan is very similar to Germany in this respect.

4.3.4 United States

In 2017, the United States was the largest oil and gas producer in the world. Globally it ranks tenth with regard to oil reserves and fourth with regard to gas reserves (EIA 2018a, EIA 2018b). New technologies in particular, including fracking, have enabled the extraction of additional resources. This is also reflected in Figure 4.3 and Figure 4.4, where the proven reserves increase between 2005 and 2015, despite increased consumption. Looking at it from this perspective, one can conclude that the United States has limited incentives to develop alternative technologies.

4.3.5 Brazil

Brazil has some sizeable reserves of gas, and even more so of oil. Recent discoveries offshore increased its domestic oil production and proven reserves. Oil import dependence in the 1970s led to the use of sugar cane for ethanol production, some of which is used for powering passenger cars. Since 1980 oil production has increased tenfold, while there has been a twofold increase in consumption. The demand for gas increased 25-fold in the same period, and self-supply is declining. However, neighbouring Bolivia is currently supplying Brazil with cheap gas. As with the U.S., the conclusion is that Brazil has limited incentives to develop alternative technologies.

4.3.6 China

In 2017, China ranked 13th in the world with regard to oil reserves and 8th with regard to gas reserves (EIA 2018a, EIA 2018b). The proven gas reserves – for example the new reserves in the South Chinese Sea – supersede demand significantly. With regard to oil, the relationship between proven reserves and annual consumption (Figure 4.3) indicates the quickly declining self-supply situation for China. Owing to an eightfold increase in demand between 1980 and 2015, it looks likely that the country will experience dependency on oil imports in the foreseeable future. Thus, while gas may provide an alternative energy source, the declining trend in domestic oil supply means that China may well have some incentive to develop alternative technologies.

4.3.7 India

India shows a picture comparable to China, though at lower levels in terms of both production and consumption. India's consumption of oil has increased sixfold in the period 1980–2015, and that of gas twofold in the same period. Self-supply by means of domestic resources is thus still possible, but is becoming less assured. Thus, while gas may provide an alternative energy source, India may, all the same, have some incentive to develop alternative technologies owing to the declining trend in its domestic oil supply.

4.3.8 Russia

Russia has a stable domestic supply of oil and gas and therefore would seem to have little incentive to develop alternative propulsion technologies.

4.3.9 South Africa

South Africa has practically no domestic oil reserves and only limited gas reserves, although the latter situation coexists with a low consumption level. Thus South Africa is a country dependent on both oil and gas imports, which implies that it has incentives to develop alternative technologies. Relevant to this discussion is the fact that South Africa produces liquid fuels from coal, which is abundantly available.

4.4 Electric Mobility

With regard to electricity, we made an investigation into the national resources from which electricity could be generated, and how those have developed since 1990 (Figure 4.5). We hereby assume that the production of electricity creating low CO2 emissions per gigawatt hour (GWh) may encourage the technological shift from fossil fuels to electricity as a result of climate protection concerns. As a rule of thumb, at a level of about 500 gCO2/kWh electricity or lower, a medium-sized electric passenger car will be responsible for generating lower greenhouse gas emissions per kilometre than a conventionally fuelled one.

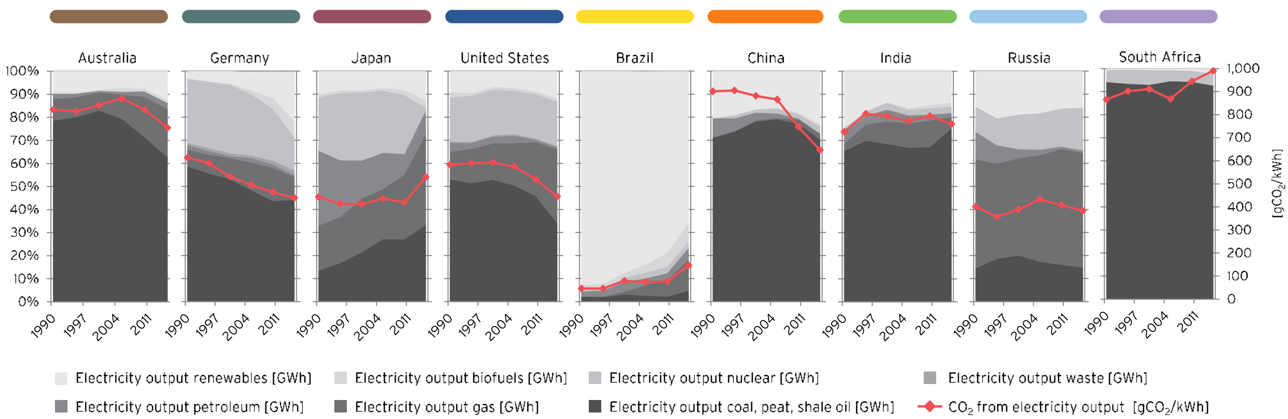


Figure 4.5. Development of the National Electricity Mix Between 1990 and 2015

SOURCE: Own depiction based on IEA (2018).

NOTE: The coloured areas refer to the left axis in terms of percentage of total electricity produced; the red line refers to the right axis in terms of CO2 per kWh.

4.4.1 Australia

Australia's electricity production relies heavily on coal. However, since 2000 the production by means of renewables and gas has been increasing. In 2015, electricity production caused 755 gCO_2/kWh output (IEA 2018). This trend is declining, meaning that electricity is becoming less greenhouse gas emitting.

4.4.2 Germany

Germany is characterised by a fast-increasing production of renewable electricity. However, coal still provides substantial primary resources for electricity production. Plans are in place to phase out nuclear and coal. The role played by gas in generating electricity may increase in the future. With 450 gCO_2/kWh and a declining trend (IEA 2018), Germany is beginning to see the benefits of encouraging electric mobility.

4.4.3 Japan

Japan's power sector has been dominated by nuclear, petroleum and gas. However, since all nuclear power plants were shut down in the aftermath of the Fukushima catastrophe, Japan temporarily switched to using more coal for its electricity generation. In 2015 it produced 540 gCO_2/kWh electricity. This was an increase from around 430 gCO_2/kWh in earlier years (IEA 2018). It is likely that nuclear power plants will be brought back into service, and renewable energy sources are also increasing.

4.4.4 United States

The United States produces electricity using a broad mix of resources. In recent years, gas and renewable sources have both increased their share, reducing the share of coal within the electricity mix. With 450 gCO_2/kWh (IEA 2018) and a downward trend, the United States is starting to see the benefits of increasingly widespread electric mobility.

4.4.5 Brazil

Brazil uses renewable energies for a large proportion of its electricity production. Most of this comes from hydropower – but the national capacity to generate hydropower is now more or less exhausted. In recent years, Brazil has turned increasingly to biofuels and gas for its electricity production. With 157 gCO_2/kWh in 2015 (IEA 2018) – a number that, although low, is increasing – Brazil would generate climate benefits by making a shift towards electric mobility.

4.4.6 China

China's domestic demand for electricity has grown more than ninefold between 1990 and 2015. China's two main sources of electricity are coal and renewables, and the latter has increased its share in the electricity mix in recent years. The CO_2 emissions per unit of electricity has declined from around 900 gCO_2/kWh to 657 gCO_2/kWh in 2015 (IEA 2018). Since the trend is towards a reduction in this figure, China may see benefits to reduce climate gases from moving towards electric mobility in the future.

4.4.7 India

India has seen a strong increase in electricity demand, and in terms of its generation the share of coal is both high and increasing; other sources are gas and renewable energies. With 771 gCO_2/kWh (IEA 2018), India would currently not benefit from the implementation of electric mobility in terms of climate protection.

4.4.8 Russia

Russia's electricity demand has been increasing since 1990. Russia makes its electricity mostly from gas, followed by nuclear, renewables and coal. Its CO_2 footprint from electricity lay in 2015 at 395 gCO_2/kWh (IEA 2018). Russia would thus benefit from the implementation of electric mobility.

4.4.9 South Africa

South Africa's electricity sector relies heavily on coal, which is domestically sourced. Another source is nuclear power. With 990 gCO_2/kWh (IEA 2018), South Africa has the highest value of CO_2 output per unit of electricity of all the study countries. Electric mobility would not create benefits with regard to climate protection.

4.5 Expert Judgement on Propulsion Systems in the Future

After presenting the information on energy supply, we also asked the experts in the workshop a set of questions touching on the future development of propulsion systems, with a target year of 2050. These were, by 2050:

- What percentage of the liquid fuels stems from fossil resources?
- What percentage of the internal combustion engines are diesel fuelled?
- What percentage of passenger cars are electrically driven (without fuel cells)?

Combining the answers provides a snapshot of the possible future propulsion systems in the study countries (Figure 4.6). While the absolute percentages should be treated with caution, they reveal an interesting comparative assessment of the expected development of propulsion systems in different markets. According to this judgement, battery electric mobility will grow particularly strongly in Germany, Japan and China. The diesel engine will retain some relevance in South Africa, but is expected to largely disappear. Other fuels include fuel cell and renewable synthetic fuels, and, for Brazil, a significant portion of biofuels.

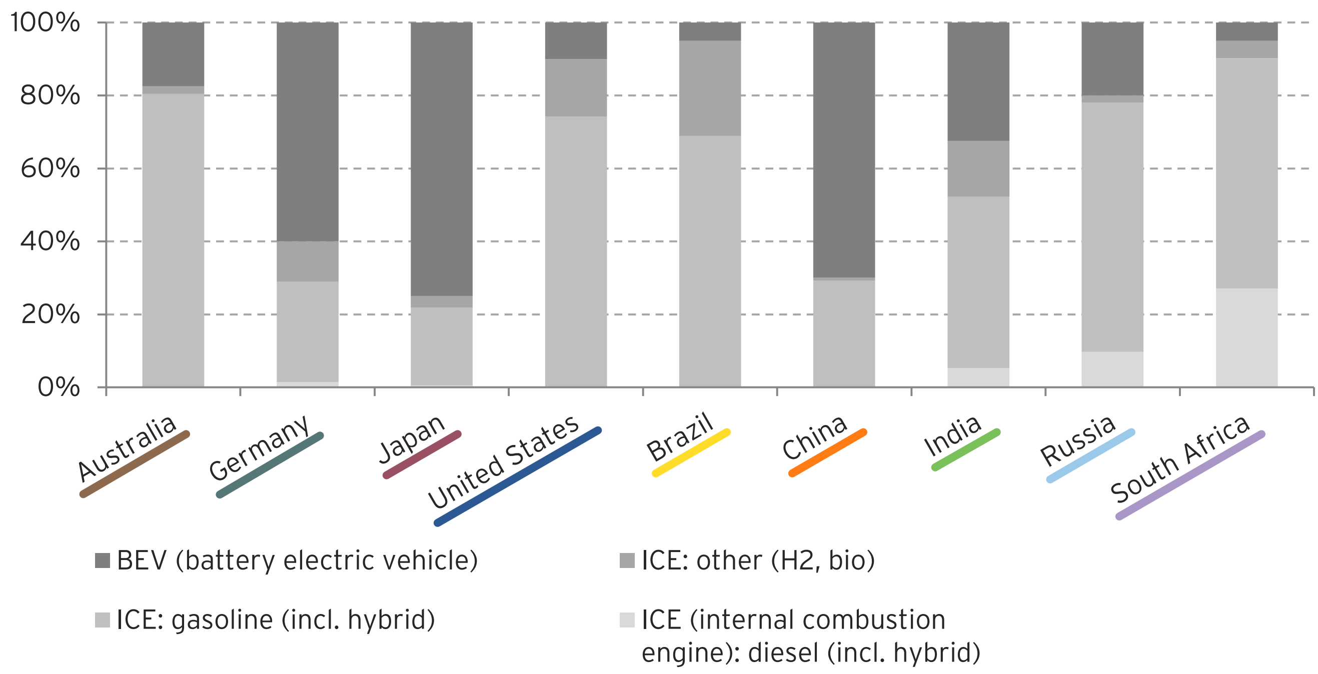
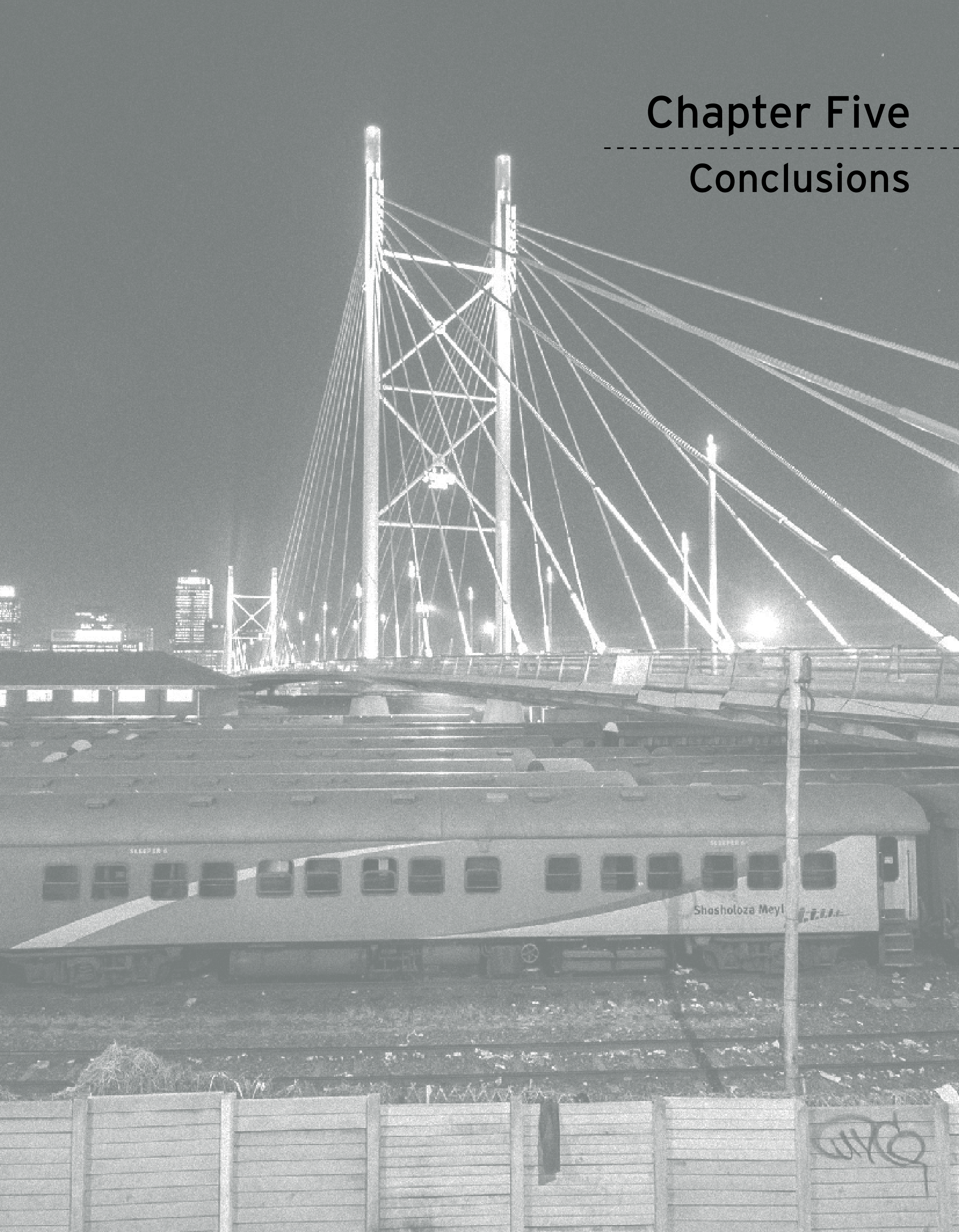


Figure 4.6. Snapshot of the Estimated Propulsion Mix in 2050

NOTE: Expert guess.

Chapter Five

Conclusions



In this study update on the future path of automobility in emerging economies, we analysed factors that influence the development of the number of vehicles per capita, as well as the VKT in the BRICS countries. The underlying assumption is that the VKT follows an S-shaped curve and reaches saturation at a certain time, reckoned to be when the BRICS countries have reached a level of personal wealth of between 35,000 and 40,000 US$2011 GDP per capita. Nine factors with a strong influence on automobility where identified beyond GDP. We combined statistical data and trends analysis with qualitative expert judgement to extrapolate the motorisation and VKT saturation curves for BRICS countries.

The factors with the greatest influence on VKT saturation levels were found to be spatial dispersion, lack of alternatives and car infrastructure, followed by active population, inexpensive driving and pro-car policies (Table 3.1). While we can observe a great diversity in the BRICS countries, some general conclusions can be drawn. For all but South Africa, the development of active population will increase VKT saturation levels. Spatial dispersion and lack of alternatives are interlinked, and depress VKT saturation levels in China, India and Russia in particular. The 'policies' intervention (factor pro-car policy) has the most pronounced effect in China, then in India, affecting VKT saturation levels negatively. On the opposite, Brazil and South Africa are expected to see factors working more in favour of their automobility, in conjunction with increasing wealth.

By classifying the factors as exogenous factors (those determined by externalities), and transport policy factors (those influenced by policy decisions), two observations can be made when comparing the updated figures with those from the original study: first, the exogenous factors in this study update point more strongly towards an increase in automobility within BRICS countries. Second, the transport policy factors are expected to more strongly dampen the trend to automobility.

Corresponding to their negative automobility scores, to which VKT saturation is closely correlated, China and India are expected to reach the lowest VKT saturation levels of the BRICS countries, somewhere between those of Japan and Germany (Figure 3.4). South Africa is expected to display the highest VKT saturation levels, with Brazil and Russia lying in the middle. However, this conclusion needs to be read in conjunction with the time horizon, i.e. when each of those countries are expected to reach the levels of 35,000 to 40,000 US$2011 GDP per capita:

- Russia: 8,900 to 9,300 VKT per capita by the late 2020s
- China: 6,000 to 6,700 VKT per capita by the early 2030s
- Brazil: 9,900 to 10,200 VKT per capita by the late 2050s
- South Africa: around 12,700 VKT per capita by the late 2050s
- India 5,700 to 6,500 VKT per capita by the mid-2060s.

It is thus the two most populous countries that are assigned the lowest expected VKT saturation levels, and India will not have reached those levels until several decades later on this century. Furthermore, while we are confident about VKT as an indication of overall demand for transport, this demand might be satisfied by vehicle types other than the individually owned passenger car.

This point also makes it more difficult to project car ownership rates. By analysing the car ownership rates seen in the OECD countries, we formed an expectation that car ownership levels will lie somewhere between 280 cars per 1,000 population (the lowest estimate, for India) and 730 cars per 1,000 population (the highest, for South Africa).

The findings of this study are of great value for analysing the future path of mobility globally. Although the projections are by necessity associated with a degree of uncertainty, they provide guiding figures for evaluating, for example, developments in the passenger car market, or the potential climate impact of future transport. In this context, DLR is further researching automobility pathways and climate impacts by means of institutionally funded projects.

Appendix A

Factor Fact Sheets: Flag Game Results

A.1 Active Population

This factor describes the share of population at a stage in life that is characterised by high mobility rates. This includes both demographic effects (i.e. age groupings in which mobility is typically high) and workforce participation (i.e. the share of the working-age population who are actually in work – influenced greatly by female labour participation, for example).

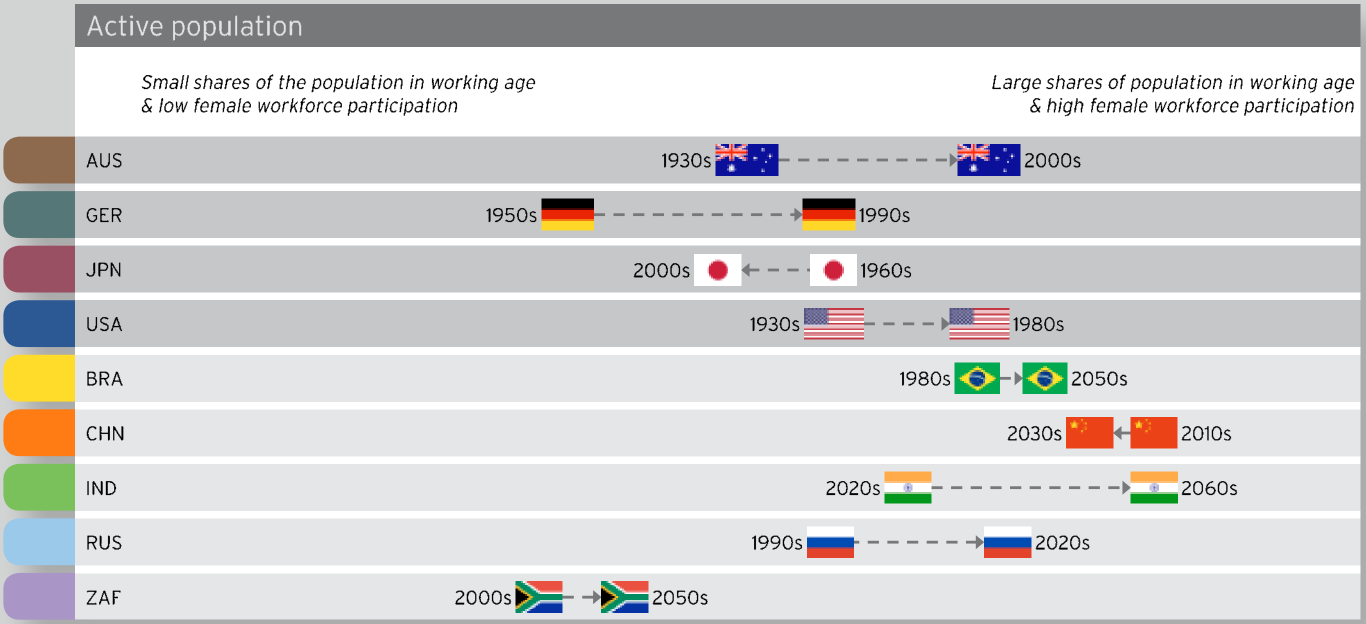


Figure A.1. Flag Game Results for Factor Active Population

A.2 Spatial Dispersion

This factor describes the urbanisation trends and the population density in built-up areas in the study countries, as a joint indicator for particular mobility developments.

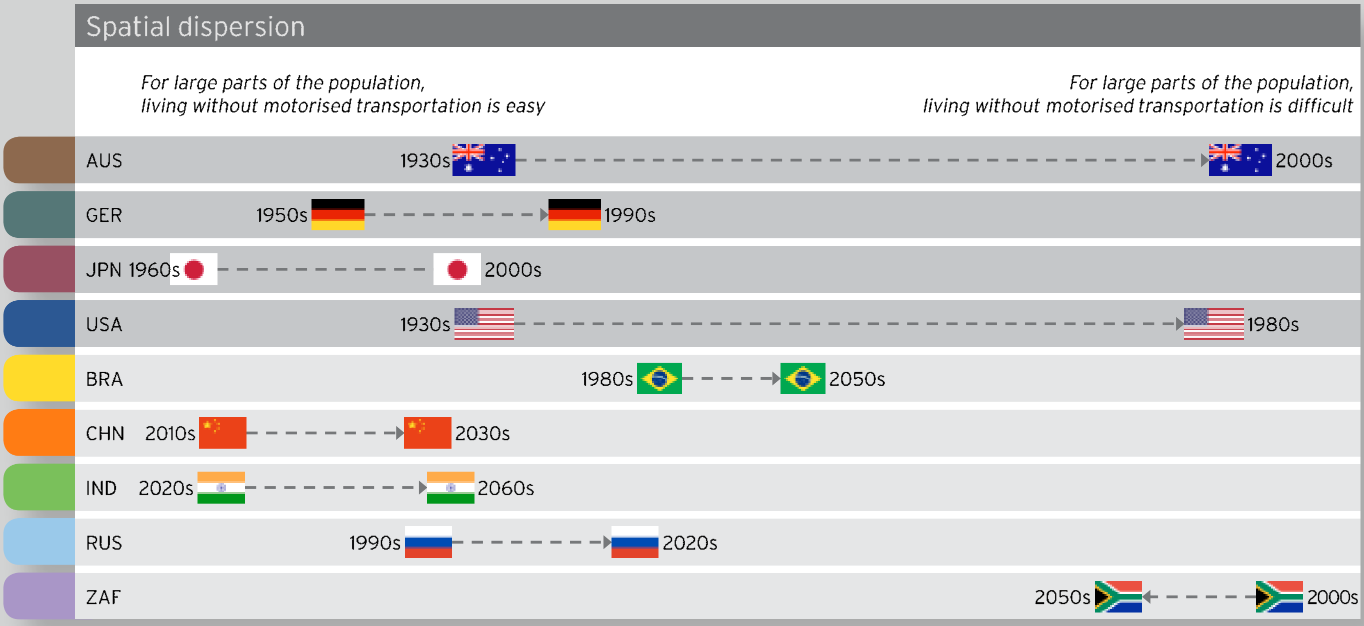


Figure A.2. Flag Game Results for Factor Spatial Dispersion

A.3 Domestic Car Industry

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

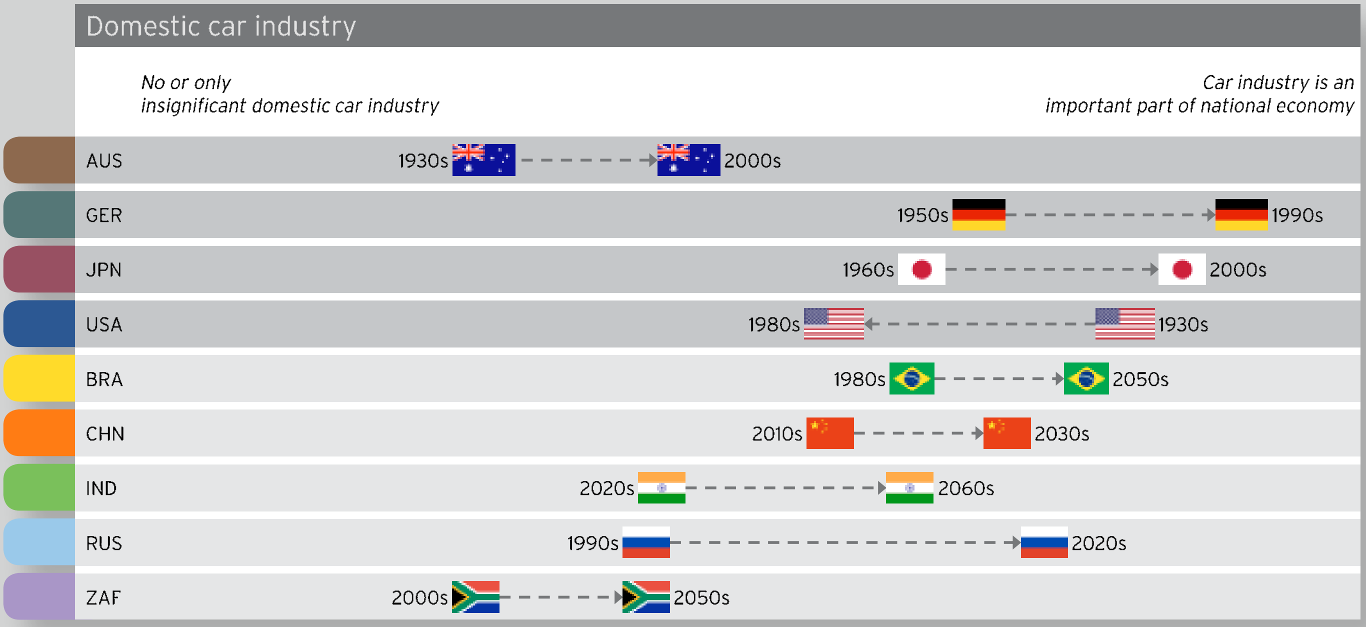


Figure A.3. Flag Game Results for Factor Domestic Car Industry

A.4 Car Infrastructure

This factor comprises all infrastructure for automobility, taking into account both the quality and quantity of roads and the parking supply.

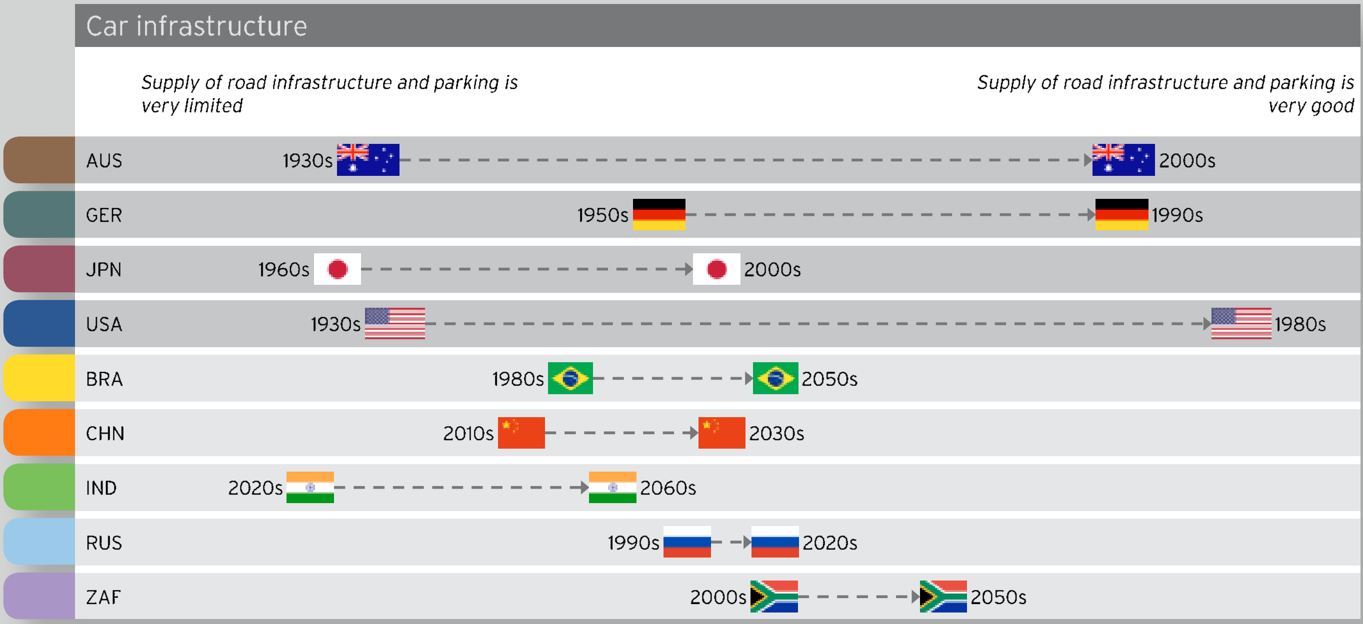


Figure A.4. Flag Game Results for Factor Car Infrastructure

A.5 Lack of Alternatives

This factor describes how car-focused the transport supply in a country is vis-à-vis the infrastructure in place for alternative modes of urban and interurban travel.

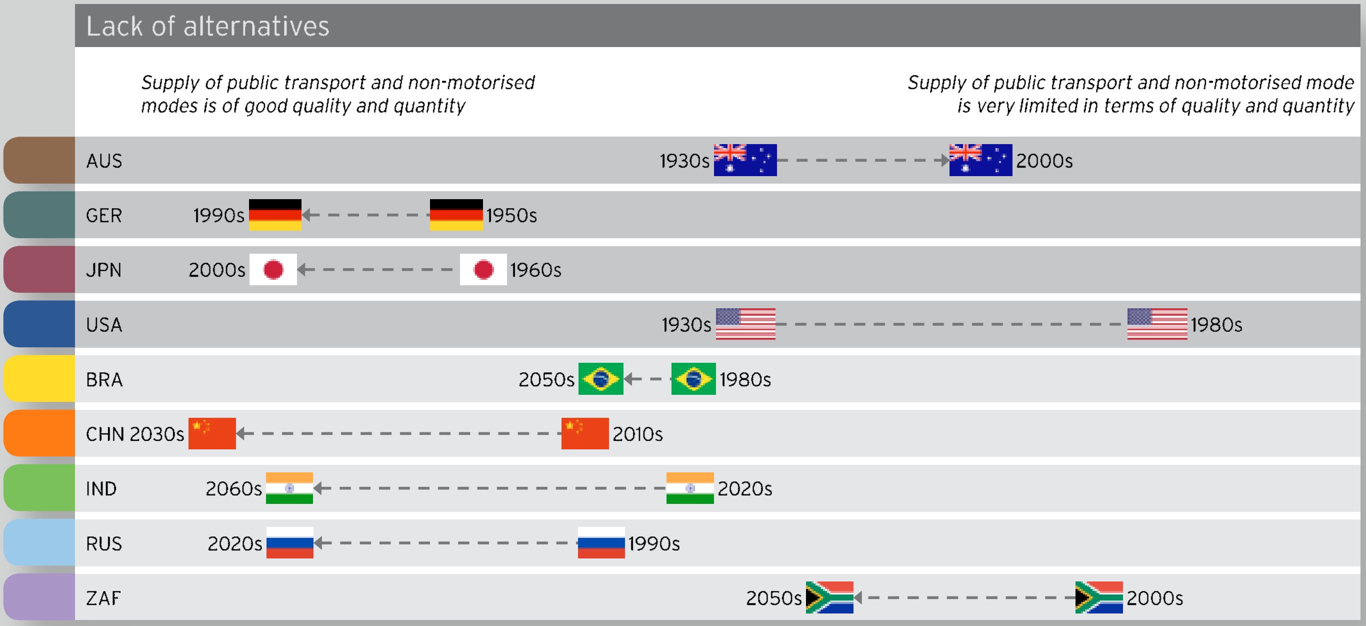


Figure A.5. Flag Game Results for Factor Lack of Alternatives

A.6 Pro-Car Policies

This factor comprises non-infrastructural policies and legislation concerning car ownership and use. This ranges from vehicle taxes (not fuel tax, which is included in the next figure), through vehicle inspection regulations, to car usage fees (tolls) and restrictions to city access.

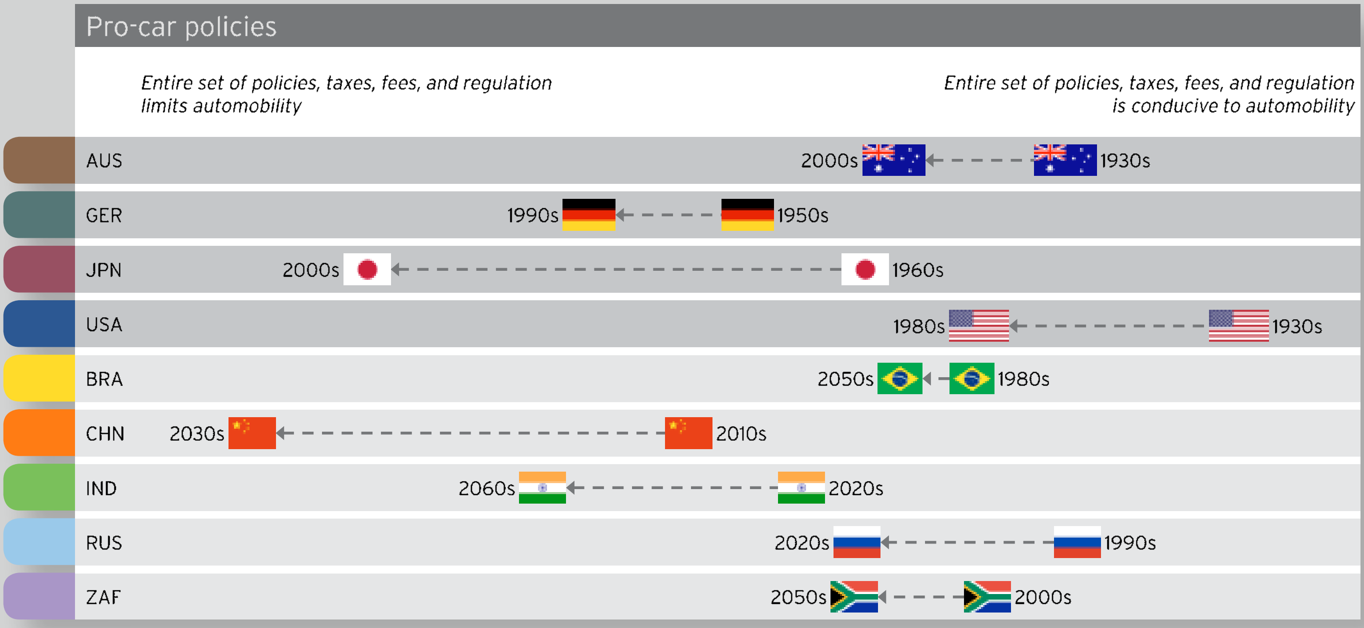


Figure A.6. Flag Game Results for Factor Pro-Car Policies

A.7 Inexpensive Driving

This factor describes whether driving is inexpensive relative to income. This includes fuel prices as well as fuel taxes.

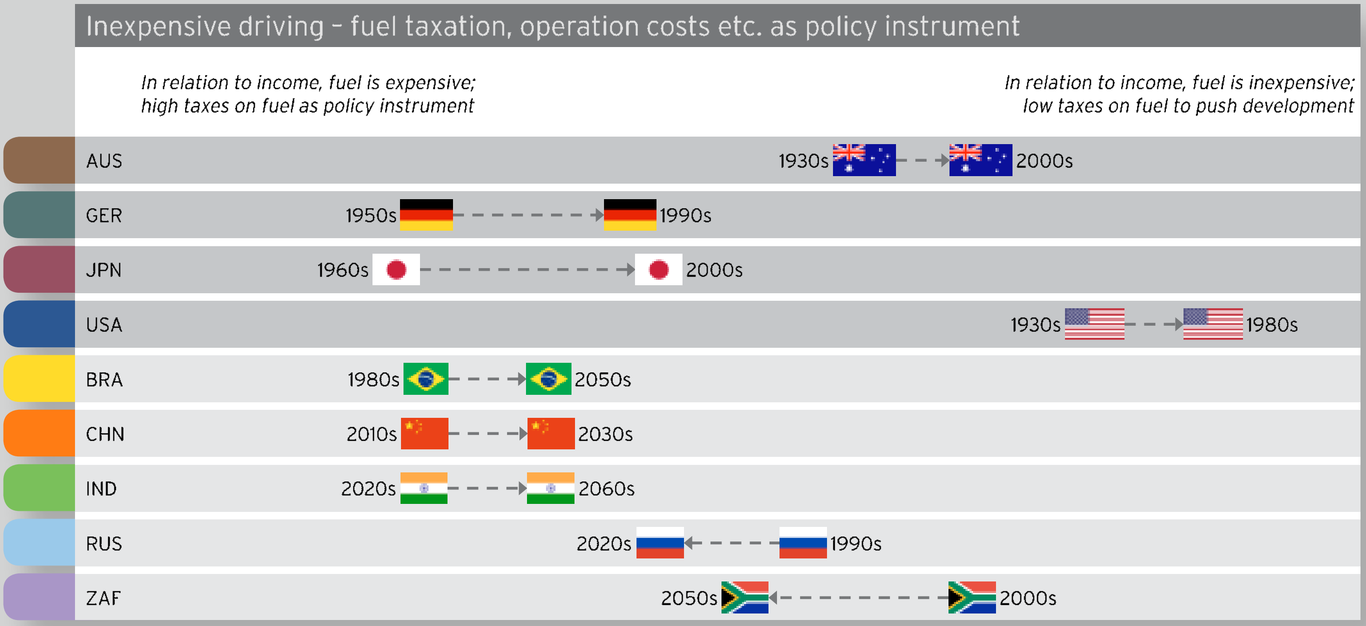


Figure A.7. Flag Game Results for Factor Inexpensive Driving

A.8 Car Culture

This factor describes the affinity to cars from a cultural perspective and the way it affects car ownership and use.

Figure A.8. Flag Game Results for Factor Car Culture

Appendix B

Country Mobility Experts

Country	Expert Name	Affiliation
Australia	Jeffrey R. KENWORTHY	University of Applied Science, Frankfurt am Main
Brazil	Antonio Nelson Rodrigues DA SILVA Luiz Afonso DOS SANTOS SENNA	University of São Paulo Federal University of Rio Grande do Sul, Porto Alegre
China	LU Huapu PAN Haixiao	Tsinghua University, Beijing Tongji University, Shanghai
Germany	Tobias KUHNIMHOF Thomas R. MEISSNER Peter PHLEPS	German Aerospace Center, Institute of Transport Research, Berlin BMW, Munich ifmo Institute for Mobility Research, Munich
Japan	Toshiyuki YAMAMOTO	Nagoya University, Nagoya
India	Senathipathi VELMURUGAN Ashish VERMA	Council for Scientific and Industrial Research (CSIR), New Delhi & Central Road Research Institute (CRRI), New Delhi Indian Institute of Science (IISc), Bangalore
Russia	Christian BÖTTGER Vadim DONCHENKO	A+S, St Petersburg Scientific and Research Institute of Motor Transport (NIIAT), Moscow
South Africa	Johan W. JOUBERT Mathetha MOKONYAMA	Centre for Transport Development, Department of Industrial and Systems Engineering at the University of Pretoria, Pretoria Council for Scientific and Industrial Research (CSIR), Pretoria
United States	Johanna ZMUD	RAND Corporation, Arlington (Virginia)

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Figures and Tables

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Abbrevations

ABS	Australian Bureau for Statistics
ACEA	European Automobile Manufacturers' Association
AIDS	acquired immune deficiency syndrome
AS	automobility score
AUS	Australia
BEV	battery electric vehicle
BITRE	Bureau of Infrastructure, Transport and Regional Economics (Australia)
BMVI	Bundesministerium für Verkehr und digitale Infrastruktur (Federal Ministry of Transport and Digital Infrastructure, Germany)
BMW	Bayerische Motorenwerke
BRA	Brazil
BRICS	Brazil, Russia, India, China, South Africa
BRT	bus rapid transit
CAFE	Corporate Average Fuel Economy (USA)
CHN	China
CIA	Central Intelligence Agency
CO2	carbon dioxide
CRRI	Central Road Research Institute (India)
CSIR	Council for Scientific and Industrial Research (New Delhi); Council for Scientific and Industrial Research (South Africa)
DESTATIS	Statistisches Bundesamt (Federal Statistical Agency, Germany)
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V. (German Aerospace Center)
DW	Deutsche Welle
e.g.	exempli gratia
EIA	U.S. Energy Information Administration
et al.	et alii
g	gram

GDP	gross domestic product
GER	Germany
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Corporation for International Cooperation)
GWh	gigawatt hour
HIV	human immunodeficiency virus
ICE	internal combustion engine
i.e.	id est
IEA	International Energy Agency
ifmo	Institute for Mobility Research
IIASA	International Institute for Applied Systems Analysis
IISc	Indian Institute of Science
IISD	International Institute for Sustainable Development
incl.	including
IND	India
IPI	Imposto sobre Produtos Industrializados (Portuguese tax on industrialised products)
ISO	International Organization for Standardization
ITF	International Transport Forum
JPN	Japan
km	kilometre
kWh	kilowatt hour
LCU	local currency unit
MLIT	Ministry of Land, Infrastructure, Transport and Tourism (Japan)
MORTH	Ministry of Road Transport and Highways (India)
NCR	National Capital Region
NEV	New Energy Vehicle
NGT	National Green Tribunal

NIIAT	Scientific and Research Institute of Motor Transport (Moscow)
OECD	Organisation for Economic Co-Operation and Development
OICA	International Organization of Motor Vehicle Manufacturers
PPP	purchasing power parity
R&D	research and development
RFA	Renewable Fuels Association
RUS	Russia
SSP	Shared Socioeconomic Pathways
UITP	International Association of Public Transport
UN	United Nations
UN DESA	United Nations, Department of Economic and Social Affairs, Population Division
UNECE ITC	United Nations Economic Commission for Europe/ Inland Transport Committee
U.S.	United States
USA	United States of America
U.S. DOT – BTS	U.S. Department of Transportation – Bureau of Transportation Statistics
U.S. DOT – FHWA	U.S. Department of Transportation – Federal Highway Administration
VDA	Verband der Automobilindustrie (German Association of the Automotive Industry)
VKT	vehicle-kilometres travelled
WDI	World Development Indicators
WEF	World Economic Forum
ZAF	South Africa

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