ITDP

A Global High Shift Scenario:

Impacts And Potential For More Public Transport, Walking, And Cycling With Lower Car Use

November 2014

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Published by





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Acknowledgments

The authors wish to thank the Ford Foundation, ClimateWorks Foundation, and Hewlett Foundation for their generous financial support, which made this work possible.

We also thank the individuals who participated in meetings of the advisory committee for this sustainable transport scenarios study, some of whom offered invaluable access to survey and cost data collected by the World Bank, Asian Development Bank, and InterAmerican Development Bank, and field offices of the Institute for Transportation and Development Policy, World Resources Institute/EMBARQ, and other NGOs. Members of that group include Shomik Raj Mehndiratta, Andreas Kopp, Roger Gorham, Dario Hidalgo, Ramiro Alberto Rios Flores, Ko Sakamoto, Rafael Acevedo Daunas, Cornie Huizenga, Francois Cuenot, Karl Fjellstrom, Xiaomei Duan, Shreya Gadepalli, Bernardo Baranda, Ulises Navarro, Clarisse Linke, and Yoga Adiwinarto.

Without that support we would not have been able to advance the new approach to evaluating the equity impacts of alternative transportation investments that was developed for this study. Thanks also to staff at the International Energy Agency, International Transport Forum, and Organization for Economic Cooperation and Development (OECD) who shared insights and methods they are developing to apply the IEA MoMo model more effectively to consider the full range of avoid-shift-improve sustainable transport strategies, especially Aimee Aguilar Jaber, Philippe Crist, Jean Francois Gagne, and Francois Cuenot. This analysis is partially based on the Mobility Model developed by the International Energy Agency, © OECD/IEA 2014, but the resulting analysis has been prepared by the University of California Davis and does not necessarily reflect the views of the International Energy Agency.

Special thanks to staff at the Union International des Transports Publique (UITP), especially to Jerome Pourbaix, who developed much of the initial global public transport database from which our work started. Their analysis of the potential impacts of UITP's PTx2 Campaign with the IEA MoMo model served as one of the initial inspirations for this more in-depth evaluation. Our analysis validates the importance of voluntary commitments made by UITP, the International Railways Association UIC, and by cities and groups including C40, United Cities and Local Governments (UCLG), and the International Council for Local Environmental Initiatives (ICLEI) at the September 2014 United Nations Global Climate Summit. We are pleased that the C40's report for the Climate Summit, Advancing Climate Ambition: Cities as Partners in Global Climate Action, has also drawn on results from our study. We look forward to further cooperation in all of these vital voluntary commitments.

We would like to thank Kate Blumberg, Cristiano Facanha, and Joshua Miller of the International Council on Clean Transportation (ICCT) for their generous support in applying the ICCT Roadmap model to evaluate air pollution and health impacts of the baseline and High Shift scenario, and summarizing their work in the results chapter on Air Pollution and Public Health.

Finally, the authors thank all the members of the Research Team at UC Davis and ITDP who carried out much of the data gathering, data cleaning, and data refinement and analysis work. In particular, Rosaria Berliner made an invaluable contribution to the project throughout. She and Jacob Mason did valuable work to extend and refine the global public transportation database developed for this project. We are also grateful to Duaa Getanni of UC Davis and Colin Hughes, Jemilah Magnusson, and Aimee Gauthier of ITDP, and Dan Klotz of Burness Communications, who helped manage elements of the project and its strategic communications. Paulo Humanes and Andre Münch of Planning Transport Verkeher AG helped us consider how to integrate safety issues into this study in work that is still ongoing and on which we hope to report soon.

Many other people too numerous to name helped this project succeed, and we thank them. Of course, the flaws in the end product are the responsibility of the authors alone.

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Executive Summary

This report is the first study to examine how major changes in urban transport investments worldwide would affect urban passenger transport emissions as well as mobility by different income groups. It starts with the most recent United Nations urban population forecasts and the most recent model framework and forecasts used by the International Energy Agency (IEA) for global mobility modeling. The study extends these with new research on the extent of various urban passenger transport systems in cities across the world, as well as new estimates of the extent of mobility by non-motorized transport and low power e-bikes.

The study considers two main future scenarios: a baseline urban scenario calibrated to the IEA 2012 Energy Technology Perspectives 4° scenario and a newly developed alternative scenario called "High Shift" (HS), with far greater urban passenger travel by clean public transport and non-motorized modes than in the baseline and a decrease in the rates of road construction, parking garages, and other ways in which car ownership is encouraged.

The study concludes that this High Shift scenario could save more than $100 trillion in public and private capital and operating costs of urban transportation between now and 2050, and eliminate about 1.7 gigatons of carbon dioxide (CO_2) annually—a 40 percent reduction of urban passenger transport emissions. This would cut these emissions cumulatively by about a quarter by 2050. This suggests that one of the more affordable ways to cut global-warming pollution is to design cities to give people clean options for using public transportation, walking, and cycling. In recent years, transportation, driven by rapid growth in car use, has been the fastest-growing source of CO_2 in the world. In the High Shift scenario, global car fleets would grow to 1.6 billion by 2050 instead of tripling to 2.3 billion under the baseline—a 30 percent drop.

Transportation in urban areas accounted for about 2.3 gigatons of CO_2 in 2010, almost one quarter of carbon emissions from all parts of the transportation sector. Rapid urbanization—especially in fast-developing countries like China and India—will cause these emissions to nearly double worldwide by 2050 without changes in policy and investments.

Among the many countries and regions examined in this global study, three stand out:

- **United States:** Currently the world leader in urban passenger transportation CO_2 emissions, with 670 megatons annually, the U.S. is projected to lower these emissions to 560 megatons by 2050 because of slower population growth, higher fuel efficiencies, and the decline in driving per person that has already started as people move back to cities. But this pace can be sharply accelerated with more sustainable transportation, dropping by half to 280 megatons, under the High Shift scenario. For the U.S. in particular, this scenario includes not only mode shifting but also considerable reductions in urban kilometers of travel per person through urban recentralization and substitution of telecommunications for travel.

- **China:** CO_2 emissions from transportation are expected to mushroom from less than 200 megatons annually today to nearly 1,200 megatons (1.2 gigatons) in 2050, due in large part to the explosive growth of China's urban areas, the growing wealth of Chinese consumers, and their dependence on automobiles. But this increase can be slashed to fewer than 700 megatons under the High Shift scenario, in which cities develop extensive BRT and metro systems. Total kilometers of travel do not drop significantly for China in HS. The latest data show China is already sharply increasing investments in public transport.

- **India:** CO_2 emissions are expected to leap from about 70 megatons today to over 500 megatons in 2050, also because of growing wealth and urban populations. But this increase can be moderated to only 350

megatons under HS by addressing crucial infrastructure deficiencies in India's public transport systems and slowing the growth in car use.

While this study has not focused on further actions to boost motor vehicle fuel economy, it takes into account existing policies that, in the IEA baseline scenario, would reduce energy use by improving average new car fuel economy by 32% in the OECD and 23% in non-OECD countries. The High Shift scenario increases this to 36% and 27% respectively, due to improved in-use driving conditions and a slight shift to smaller vehicles. However, the Global Fuel Economy Initiative (www.globalfueleconomy.org) calls for much more: a 50% reduction in fuel use per kilometer for light-duty vehicles worldwide by 2030. Achieving the GEFI 2030 goal could reduce 700 megatons of CO_2 annually beyond the 1,700 reduction possible from a High Shift scenario. Taken together, achieving this fuel economy goal with better public transport, walking, and cycling could cut annual urban passenger transport CO_2 emissions in 2050 by 55 percent from the baseline in 2050 and 10 percent below 2010 levels. Strong fuel economy programs for other types of vehicles (medium- and heavy-duty trucks, buses, and two-wheelers) as well as vehicle electrification and adopting other low-carbon fuels are key complementary strategies to enable deep cuts in transportation sector CO_2 emissions. These options will be investigated further in relation to High Shifts in the future.

Diesel black carbon soot emissions not only contribute to climate change; as local air pollution, these emissions are a leading cause of early death, responsible for more than 3.2 million early deaths annually. Exposure to vehicle tailpipe emissions is associated with increased risk of early death from cardiopulmonary disease and lung cancer, as well as respiratory infections in children. Car and diesel exhaust also increases the risk of nonfatal health outcomes, including asthma and cardiovascular disease.

Thanks to analysis by the International Council on Clean Transportation (ICCT), this study considers the effect of motor vehicle emissions controls and changes in vehicle activity on tailpipe emissions of fine particles, or soot, and related public health impacts. While better public transport, walking, and cycling have the potential to cut air pollution, these benefits can be eroded or even reversed if buses lack the strongest emission controls. Future growth in vehicle activity could produce a four-fold increase in associated early deaths by 2050 even with a global shift to mass transit. Adoption of best-practice motor vehicle emission controls and ultralow-sulfur fuels—consistent with or better than the latest Euro 6/VI standards adopted in Europe—across most of the world could avoid 1.36 million early deaths annually. Cleaner buses alone would account for 20 percent of these benefits. Thus, such emission controls are a sensible part of any High Shift strategy.

Using a new methodology developed for this study to evaluate the equity impacts of changes in transportation systems, the study also assesses how these alternative scenarios might affect the mobility of people at different income levels in various countries and regions. This shows that the majority of the world's population currently lacks access to cars and will continue to lack access even in 2050. Under the baseline scenario, there would be much greater inequality of mobility than if cities develop more efficient and widespread public transportation and safe and attractive conditions for walking and cycling, as occurs under the High Shift scenario. In this scenario, mass transit access would more than triple for the lowest-income groups and more than double for the second-lowest-income groups. Notably, overall mobility (kilometers per person per year) evens out between income groups by 2050 compared to the baseline, providing those more impoverished with better access to employment and services that can improve their family livelihoods.

The study concludes that unmanaged growth in motor vehicle use threatens to exacerbate growing income inequality and environmental ills, while more sustainable transport delivers access for all, reducing those ills. This report's findings should help support wider agreement on climate policy, where the costs and equity of the cleanup burden between rich and poor countries are key issues. This report's findings should help support wider agreement on climate policy, where costs and equity of the cleanup burden between rich and poor countries are key issues.

Introduction

Study Background and Context

While a number of studies have focused on the effects on global warming pollution of more stringent standards for motor vehicle fuel economy, [1] emissions of local air pollutants,[2] and alternative fuels, this is the first study to examine how major changes in transport infrastructure and transit system investments worldwide would affect urban passenger transport emissions as well as mobility by different income groups.[3] The findings of the study are relevant to three concurrent policy discussions by world leaders: how to manage climate change, advance equitable and environmentally sustainable economic and social development, and manage unprecedented urbanization. To make progress, the world needs to find ways to do all these things together.[4] This report shows a way to do so.

The study, first released on the September 17, 2014 United Nations (UN) preparatory meeting for Habitat III, and discussed at events connected to the UN Secretary General's Climate Summit on September 23, 2014, contributes to concurrent discussions of Sustainable Development Goals (SDGs) recommended to the UN General Assembly. This includes an SDG focused on sustainable cities and human settlements with a key target for sustainable transportation.

This paper is the product of an 18-month research initiative by ITDP and UC Davis, with funding from the Ford Foundation and ClimateWorks Foundation, to explore an alternative future and estimate its potential impacts while considering what types of investments and policies would be needed to achieve such a future. It considers two main future scenarios: a baseline urban scenario calibrated to the International Energy Agency's (IEA) ETP2012's 4° scenario (4DS)[5] and a newly developed alternative scenario called "High Shift," with far greater urban passenger travel by clean public transport and non-motorized modes than in the baseline.

This project was inspired by the 2012 Rio+20 voluntary commitment by eight multilateral development banks to devote $175 billion toward more sustainable transport investments over the next decade[6] as well as other voluntary commitments to double public transport use and expand sustainable transport.[7] While this is only a small part of what it will take to develop the needed transport systems, these investments inspire exploration of what a shift toward more sustainable transport might look like, what it might cost, and what impacts it might have.

Urban Trends and Projections

An important aspect of the analysis is urbanization. This study uses the UN 2014 revisions of its *World Urbanization Prospects* population projections as a foundation for its urban travel projections, in particular the potential number of transit systems of different types around the world. The UN projections are shown in Figure 1. Urbanites are projected to represent about two thirds of the world's population in 2050 (6.3 billion out of 9.6 billion).

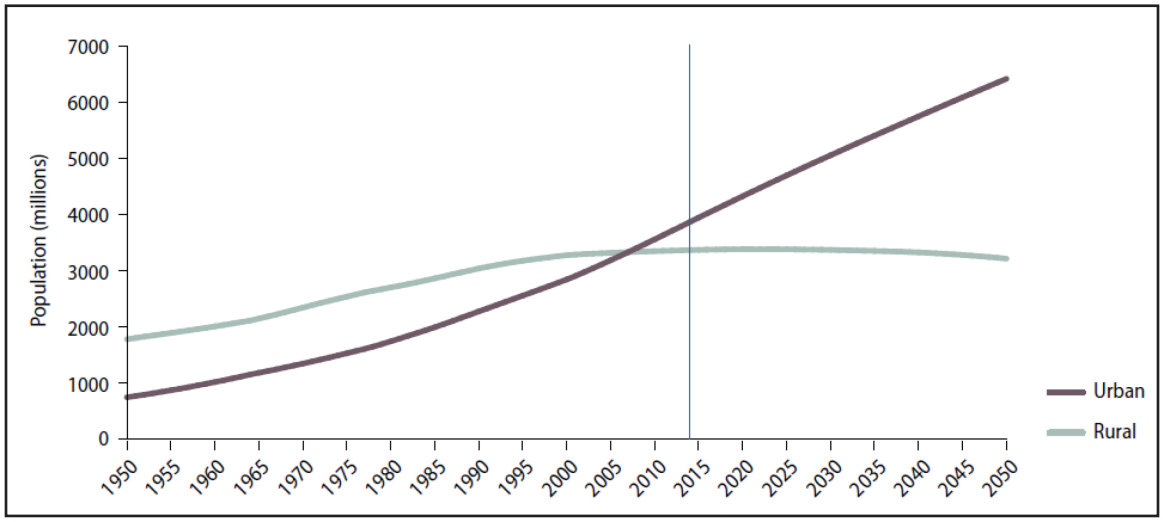


Figure 1: UN Projections of Urban and Rural Population

The growth in urban sizes is fairly evenly distributed across city size class; megacities grow considerably, as do other large cities. However, over one third of urban population remains in cities below 300,000 in size, as shown in Figure 2.

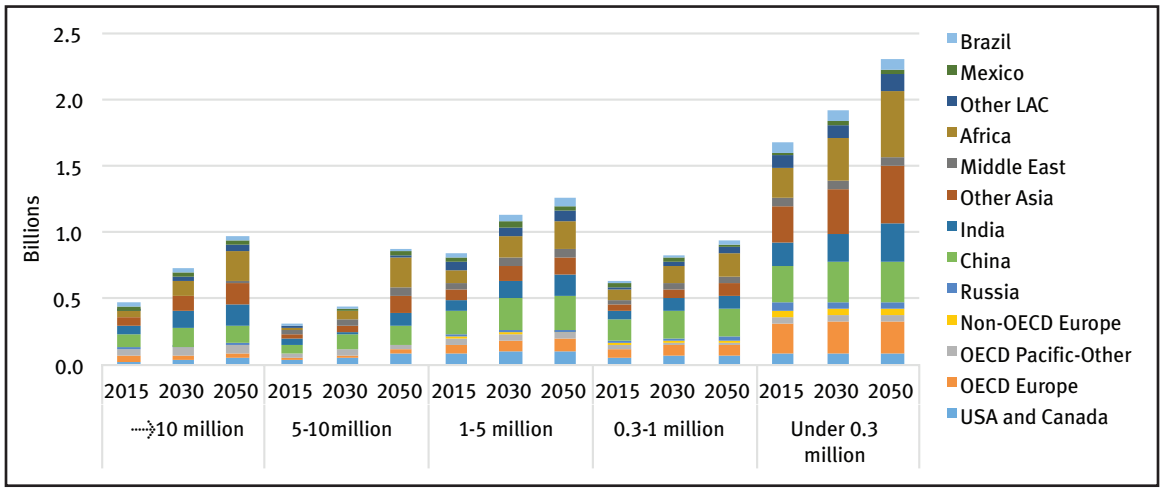


Figure 2: Projection of Urban Population by City Size

Methodology

This analysis uses a somewhat simplified "what if" approach, though with considerable regional and modal detail. It provides a base picture of urban travel around the world at a significantly higher resolution than any previous study—for example, with more modes and better estimates of passenger travel by mode. The following sections describe the methodology, data and assumptions used in the study, the baseline and High Shift scenarios, and a range of results and implications, ending with conclusions for policy-making and proposed extensions of this research.

The analysis is developed using an urban model based on IEA's Mobility Model (MoMo). MoMo is a national-level model that allows a detailed representation to be made of travel, energy use, and CO_2 emissions, and for this project this framework has been extended to focus on urban travel. MoMo contains some urban modes (e.g., city buses) and some modes accounted for only nationally (e.g., car travel). In this project, additional urban modes have been elaborated (e.g., metro, tram, commuter rail), and the urban share of all modes is estimated using the MoMo world framework of 32 countries and regions.[8] The existing national projection system and scenarios form the basis for our urban scenarios, including the baseline and alternative, High Shift scenario (HS).

Although there have been few macro studies of modal shift potential, there are important precursors to this one. The 2009 *Moving Cooler* study[9] evaluated 48 transport strategies and policies that would affect U.S. motor vehicle activity and use, bundled in various ways under different scenarios. It analyzed their impact on overall U.S. CO_2 emissions out to 2050 considering baseline and forecast travel markets using a motor vehicle stock model. This formed the foundation of a related report to Congress.[10] The IEA published an analysis of modal shift across all types of travel (with no urban breakouts) in its 2009 study *Transport, Energy and CO_2: Moving Toward Sustainability*.[11]

Baseline Scenario

The IEA ETP 2012 MoMo 4°C global warming scenario (4DS) provides the basis for this study's baseline scenario. While the IEA's 6°scenario appears to be closer to the current path the world is on, there are reasons to believe that a 4° future is more likely at this point, given recent policy activity. The 4DS scenario assumes—among other things—a global climate agreement that creates a global CO_2 pricing system to restrain greenhouse gas (GHG) emissions growth, but without sector-focused shifts in investments and policies that might flow from concerted pursuit of broader sustainable development goals.

This baseline builds on recent trends in travel around the world, including a continued strong rise in car ownership and use as incomes rise. In the urban context, car and (in some regions) motorcycle travel mode shares rise rapidly in the baseline scenario, with travel by mass transit, walking, and cycling slow-growing or stagnant in most regions. Fuel-efficiency improvements occur rapidly for a while where fuel economy standards are in place but stagnate after 2030; alternative fuels do not gain much traction, and petroleum fuels still dominate in 2050.

High Shift Scenario

The High Shift (HS) scenario has been built up assuming major departures from the baseline in terms of travel trends, particularly after 2020. The same overall growth trajectories in travel are assumed, but shifts to transit and non-motorized modes gradually occur (or moves away from these modes are greatly slowed) based on much better provision of high-quality options in cities worldwide. This in turn requires major investments in new systems and provision of infrastructure such as Bus Rapid Transit (BRT), rail, and bike lanes, which are estimated in connection with the scenario. Targets for urban and metropolitan area transit system development and associated passenger travel are linked to the UN 2014 revisions of urban population through 2050 (with explicit projections for individual cities to 2030), with urban population rising to 66% of global population, from 50% today.[12]

This High Shift scenario considers what could be if the policies and investments currently in place in the nations with the most efficient urban transport were replicated throughout the world. Assumptions in developing the HS scenario include:

- In most regions, total urban passenger mobility through 2050 (measured as passenger-kilometers) is roughly preserved from the Base scenario in the same year and region. However, in some cases (particularly the U.S and Canada) lower levels of travel are accepted as part of improved urban planning and urban re-agglomeration that lowers trip lengths, particularly in OECD countries. Africa experiences a large increase in total mobility in High Shift because a similar increase in transit and non-motorized transport (NMT) as occurs in other regions with a 50% reduction in light-duty vehicle (LDV) travel results in much higher total travel levels than in the baseline scenario.

- For private motorized modes, the ownership rates projected in the baseline that are related to income growth are overridden by assuming lower rates along with lower travel per vehicle and somewhat higher occupancy rates. All of these would need to be achieved through policy and pricing initiatives, since autonomous changes in lifestyle that might affect car ownership are already included in the baseline.

- For public transportation modes, the average number and length of systems, as well as the modal capacity, frequency, speeds, and load factors, are all increased in HS in order to generate higher passenger-kilometers (pkm) estimates. These are all checked against data on existing high-performing systems, with the idea that the future average system would perform closer to today's best systems.

Key Findings

Urban Rapid Transit Projections

A key aspect of the projections in the High Shift scenario is growth in urban rapid transit systems, particularly rapid transit such as metro, tram/light-rail (LRT), commuter rail, and bus rapid transit (BRT) systems. To project the extent of these systems, we estimated their extent in cities around the world today, and developed targets for their expansion and new construction in cities out to 2050. To identify patterns, city size analysis was undertaken in conjunction with data on system location and extent. We extended from 2030 to 2050 the UN projection of cities by city size based on the UN projection of total urban population to 2050.

Using the projection of cities of different sizes, several observational approaches were adopted to identify target levels of rapid transit system extent for different-size cities. A detailed global database of existing systems was developed and sorted by city size and region. We considered the largest systems per capita by city size by region and the average ratios of system length to population. A wide range of maxima occur with no particular pattern; cities in OECD regions—the world's wealthier countries—generally have larger systems per capita than in non-OECD regions. Europe has particularly large systems, as Table 1 shows. It also has much higher percentages of cities with systems than do most other regions.

To become a successful, efficient transit-oriented city, an urban area needs to supply a sufficiently high level of rapid transit services. A reasonable approximation of these services is the kilometers of urban rail and high-quality bus rapid transit trunk lines, which this study considers together with frequency and capacity. The High Shift scenario focuses in part on increasing the ratio of rapid transit kilometers per million urban residents (the "Rapid Transit per Resident" or RTR) in emerging economies closer to the levels found today in advanced developed economies and to boosting it further in wealthy countries where it falls short of current global best practice.

Rapid Transit to Resident Ratio	2010					2050	
	BRT	Metro	Tram/LRT	Commuter Rail	Total	Baseline Total	High Shift Total
USA/Canada	0.4	5.4	5.1	21.0	31.9	30.7	60.5
Mexico	2.5	2.2	0.7	0.3	5.7	8.7	35.2
OECD Europe	0.4	7.5	20.0	56.2	84.2	84.4	117.8
OECD Pacific/Other	0.9	7.8	2.6	66.6	78.0	81.0	106.6
Non-OECD Europe	0.0	2.1	39.7	3.2	45.0	50.8	79.9
Russia	0.0	4.6	34.8	4.7	44.1	51.0	77.8
China	0.8	3.4	0.4	0.1	4.7	7.6	43.3
India	0.3	0.7	0.2	4.1	5.3	6.1	37.5
Other Asia	0.5	1.0	1.1	2.2	4.8	5.1	19.3
Middle East	0.8	2.2	0.2	0.2	3.4	5.2	30.9
Africa	0.2	0.2	0.5	1.9	2.9	4.0	19.0
Brazil	1.7	2.0	0.0	4.4	8.0	10.8	32.4
Other Latin Am/Carrib.	1.4	1.1	0.2	8.5	11.2	13.2	32.4

Table 1: Rapid Transit to Resident (RTR) Ratio 2014 and High Shift Scenario: Km per million residents by mode and region (averaged over all cities over 300,000 population)

For example, in China in 2010, the RTR was about 5 and is projected to grow to near 8.0 by 2050 in the baseline, while in the High Shift scenario the RTR would grow to 21 by 2030 and to 43 by 2050. Similarly, in 2010 the RTR in Brazil and Mexico was about 8 and 6 respectively and is forecast to grow very slowly in the baseline, but to grow to 19 and 20 respectively by 2030 and to reach 32 and 35 respectively by 2050 under the High Shift scenario. By comparison, the RTR in the U.S. and Canada in 2010 was 32 and was 84 in OECD Europe (highest of any region), with both projected to remain flat under the baseline out to 2050, but to grow to 61 and 118 respectively by 2050 under the High Shift scenario. Note that the U.S. rapid transit systems are relatively underutilized with low passenger loadings (contributing to the very high car share). In HS, this performance aspect also rises over time, contributing to much

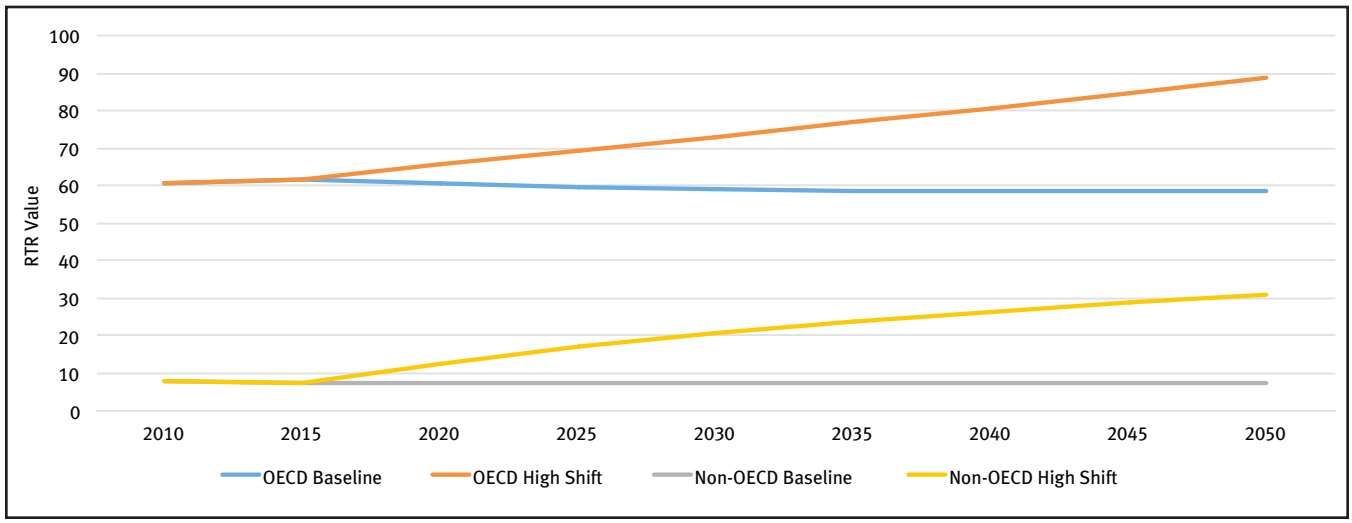


Figure 3: Rapid Transit Kilometers Per Million Resident Trends to 2050 by Scenario and Region

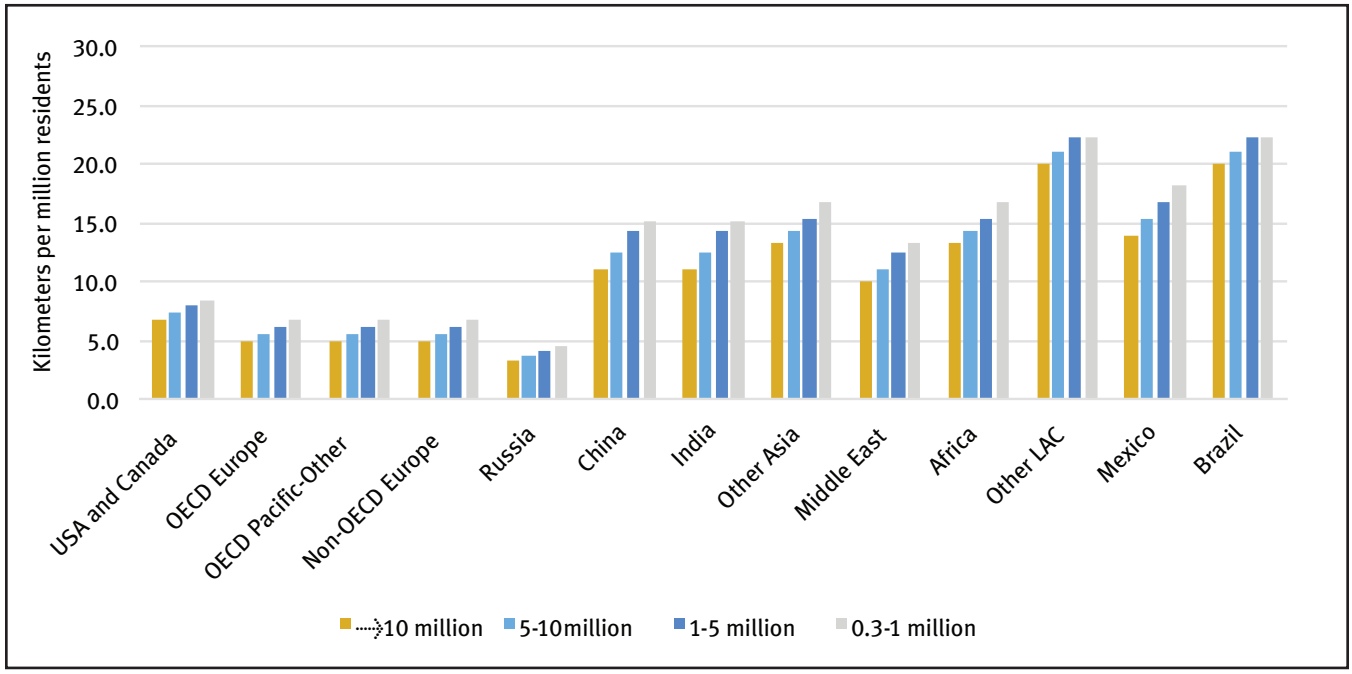


Figure 4: Illustrative Target Setting for BRT System Length in 2050 by City Size Class (Average for all cities in region) for High Shift scenario

higher transit ridership. This occurs to a lesser extent in all countries in HS.

These changes are shown over time for OECD and non-OECD in Figure 3. In both cases, the RTR grows slowly (or with a slight decline) in the baseline and grows rapidly in the High Shift scenario. Figure 4 illustrates target setting for BRT by city size by region/country. Similar target setting was done for other public transport modes.

Passenger Travel Assumptions and Results

The summary results for the OECD and non-OECD regions of the world resulting from the various projections are shown in Figure 5 for total Passenger Kilometers of Travel (PKT) and Figure 6 for PKT per capita. More detailed results for seven select regions are shown in Figures 7 and 8. To achieve the High Shift projection of urban passenger travel, the increase in travel by each mode was combined (with consideration of how much each of these modes could logically increase given increases to the others, and considering the starting points) and then compared to total travel in the baseline for each of the regions and countries in MoMo. Growth rates in non-OECD countries were adjusted to support a target 50-percent reduction in private light-duty vehicle travel, except in the U.S. and Canada, where the 50 percent reduction is much greater than a plausible offset from increased transit and NMT.

These figures show that in 2010 those in the OECD travelled almost twice as much per person as in the non-OECD, while by 2050 in the High Shift scenario, the travel per capita converges around 8,000 PKT per person per year, suggesting more equal levels of mobility than exist today or in the baseline scenario. Results in greater regional detail along with detailed assumptions and calculations are being prepared in a subsequent documentation report.

The analysis underlying the High Shift scenario suggests that urban travel needs in most parts of the world can, in principle, be met with a combination of travel modes that cut urban light-duty vehicle (LDV) kilometers by half. The required extent and use of mass transit and non-motorized modes in all areas in 2050 does not exceed the use in certain areas of the world today. However, given the rapid urbanization occurring between now and 2050, this will require public transportation to be typically two to three times higher in 2050 in High Shift than in the baseline, and in some regions many times higher than today in places where today's public transport levels of service are very low.

A key goal of the High Shift scenario is to improve the equity of mobility—this is achieved as all regions begin to converge toward 8,000 PKT per capita per year by 2050, with Africa and parts of Asia achieving higher mobility rates in the High Shift scenario via investments in public transport that are close those of other world regions, especially for buses. This goal is also achieved within each region across income groups as shown in the section on equity on the following pages.

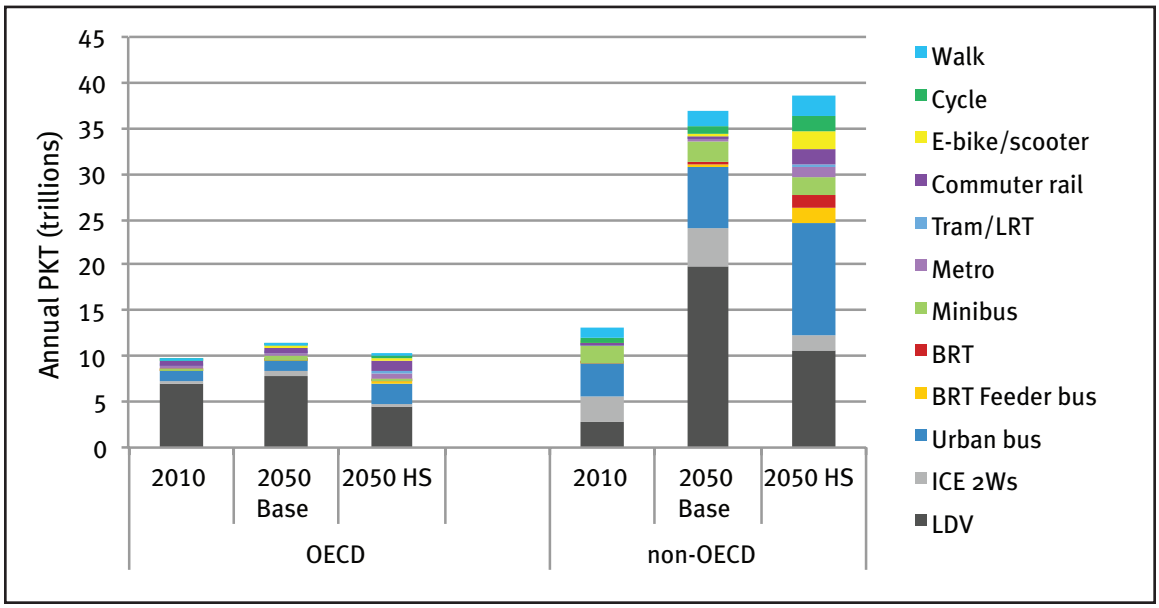


Figure 5: Total Passenger Kilometers of Urban Travel 2010, 2050 Base, and 2050 High Shift Scenario

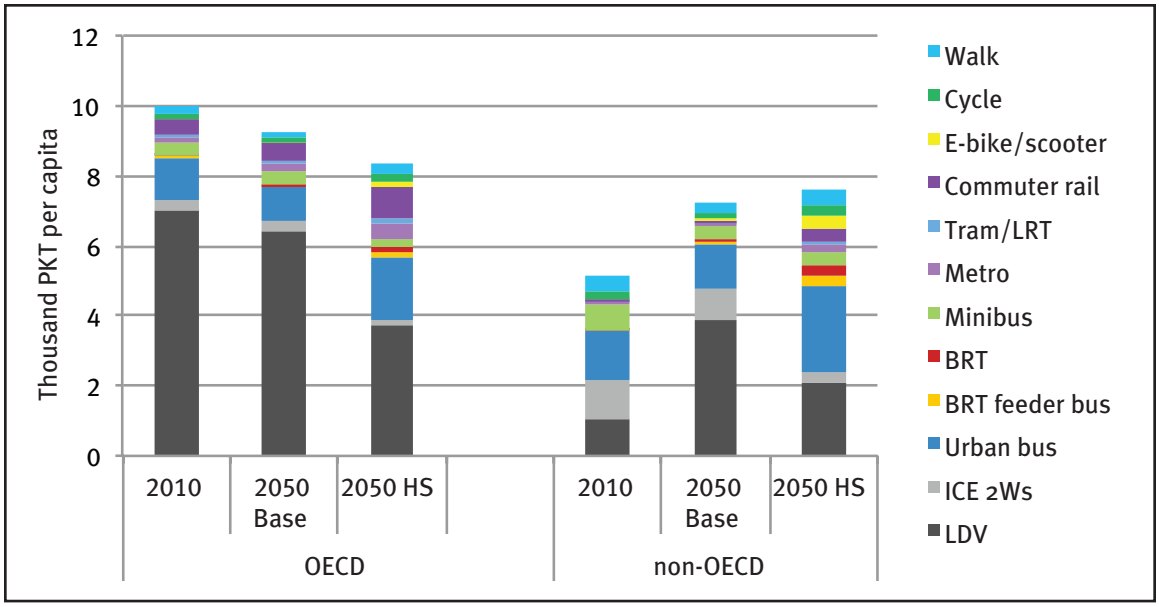


Figure 6: Passenger Kilometers Per Capita of Urban Travel, 2010, 2050 Base, and 2050 High Shift Scenario for OECD vs non-OECD

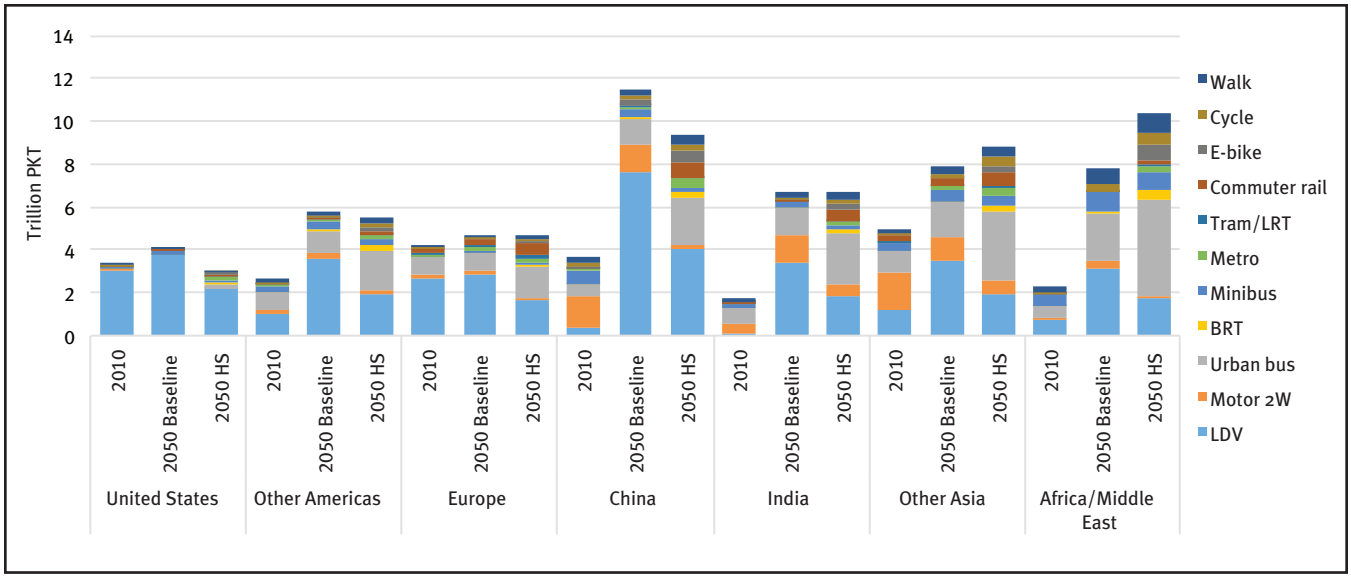


Figure 7: Total Urban Passenger Travel for Select Countries/Regions

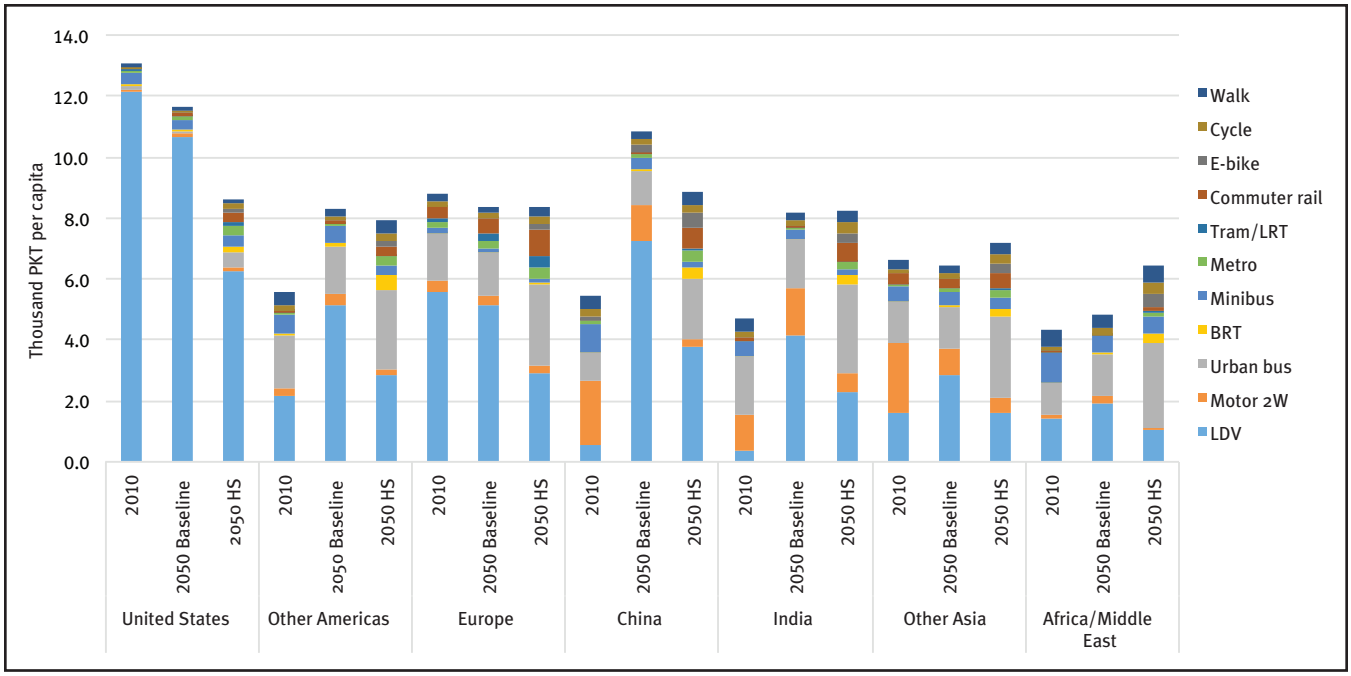


Figure 8: Travel Per Capita for Select Countries/Regions

The High Shift scenario shows a pathway to dramatically boost mobility and sustainable urban economic development in several regions of the world now held back by low mobility and diminished access to markets and opportunities. In Africa, motorization rates even in 2050 are so low that cutting LDV kilometers in half does not reduce total PKT dramatically. Increasing public transport, cycling, and e-bike use by factors only somewhat lower than in other regions results in an overall dramatic increase in African urban mobility, with total PKT in 2050 about 1.5 times higher than in the baseline. This is true to a lesser extent in "Other Asia" (Asia excluding OECD countries, China, and India).

Urban Bus Assumptions And Results

In the High Shift scenario, apart from "rapid transit" buses (BRT systems), there is steady growth in the number of conventional large buses around the world, particularly in non-OECD countries. This increase in bus service, of a high quality and frequency such as typically is provided in Europe, accounts for an important share of the overall increase in transit ridership in most regions.

Assumptions include:

- Ridership per bus is based on MoMo country data and increases from a 2010 range of 6–47 (from the lowest to highest country average, U.S. and Eastern Europe, respectively) to a range of 20–50 in 2050, with most countries in the 25–30 range by 2050. This average accounts for all bus travel, so peak times may have far higher averages but are offset by low-volume periods and back-haul trips. In contrast, in the baseline scenario, load factors generally decline.

- Minibuses (under 24 seats) typically have about 50% occupancy, with slow worldwide baseline growth in numbers and ridership in the baseline. In contrast, there is a decline in the High Shift scenario, as riders shift to larger buses and BRT. This also helps reduce traffic congestion, since far more people are carried on larger and fewer buses.

- In the High Shift scenario, by 2050 most cities have sizable BRT systems, particularly in the developing world. On a per capita basis, average system lengths approach those of cities like Bogota today. Apart from the projection of BRT system growth, BRT ridership per unit system also increases, approaching the TransMilenio system in Bogota, with similar bus capacities, load factors, and vehicle speeds. All systems achieve at least a Bronze or better rating on the *BRT Standard*, [13] by 2050 yielding 30–35 million pkm per lane-km for BRT (compared to 40–42 million pkm per lane-km for Metro, up from 12–14 and 25–35 million pkm per lane-km respectively today).

- BRT is assumed to pull riders from motorized two-wheelers, light-duty vehicles (private cars), minibuses, and regular buses.

- BRT feeder buses are assumed to carry an equal total mobility service as BRT trunk services and provide many passengers with expanded opportunities for one-seat, easy-transfer rides.

As shown in Figure 9, urban bus travel provides the major part of bus travel in most regions, increasing in the 2050 High Shift scenario by anywhere from 129% (OECD Pacific, with a very high initial level) to 445% (U.S./Canada, with very low initial levels) compared to the baseline. BRT, which shows signs of exponential growth as a newly developed form of public transportation, in all countries in the baseline 2050 increases by at least a factor of three compared to current levels. In the 2050 High Shift scenario, BRT increases by about 300% in Latin American countries (which have fairly high initial BRT levels in baseline) to 800% in India and Other Asia, which have fairly low levels compared to the baseline. A variant BRT high shift scenario is also examined below, in which BRT's share of new rapid-transit line-kilometers is 50% higher than in the primary initial HS scenario shown here.

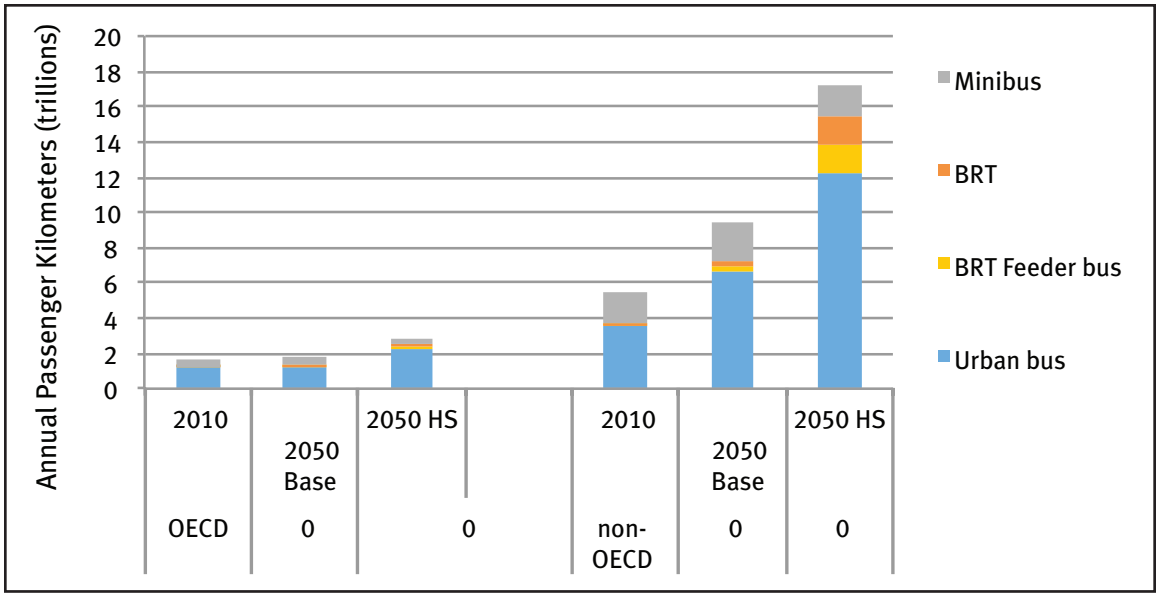


Figure 9: Bus and BRT Annual Passenger Travel By Year, Scenario, and Region

Urban Rail Assumptions And Results

A major effort was made to build up a worldwide inventory of rail systems and system characteristics (system length, ridership). The International Union of Railways (UIC) provided IEA with an initial database of tram, light rail, and metro systems, which was augmented with Internet searches and data from national, regional, and local government and transit operators. A completely new commuter rail database was constructed. In 2010, by far the highest urban rail ridership is observed in Europe and OECD Pacific. Many world regions have comparatively few systems and lower ridership levels on those systems.

Assumptions include:

- In the baseline scenario, rail systems do not expand much and not that many new systems are built, so there is only slow growth in urban rail ridership around the world.

- In the High Shift scenario, there is steady growth in the number of rail systems and ridership around the world to reach certain targets of rail access and ridership, though the levels per capita in many regions in 2050 are still well below Europe and OECD Pacific today.

- Metro, trams, and light rail are featured more in OECD countries whereas BRT is featured more in non-OECD countries, though all regions grow all systems to some extent. Commuter rail systems are expanded significantly in all regions as part of a polycentric development strategy for metropolitan areas.

Figure 10 shows the projected use of urban rail systems for OECD and non-OECD countries for 2010 and under the baseline and High Shift 2050 scenarios. It is important to note that the y-axis scale of Figures 9 and 10 differs greatly. Rail only provides 2.5 trillion passenger-kilometers of travel in 2050 HS whereas buses provide 16 trillion PKM.

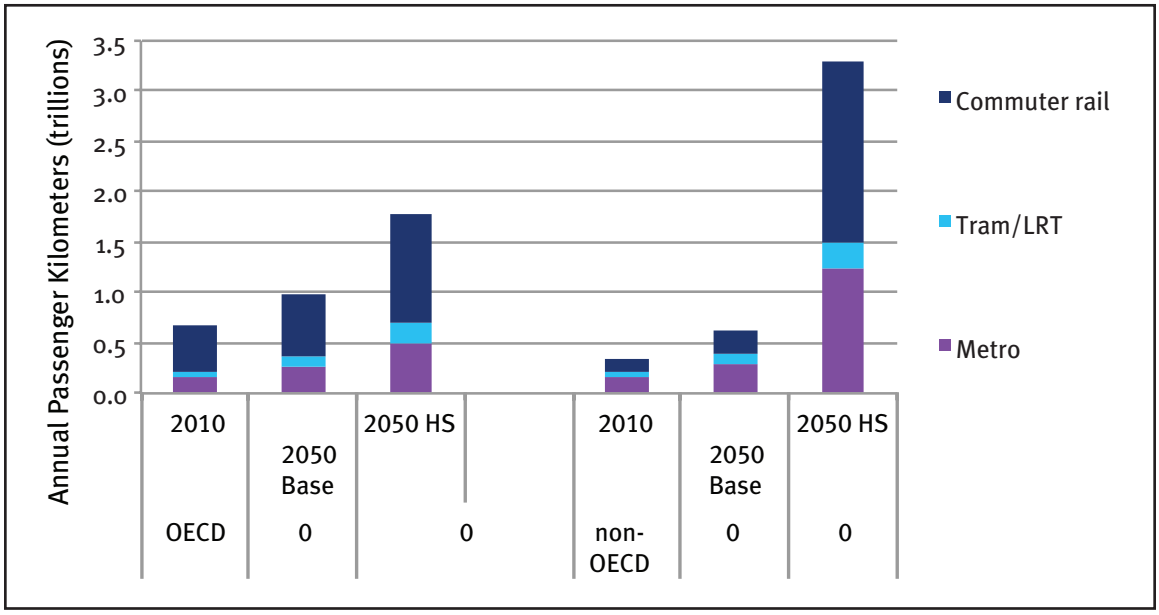


Figure 10: Passenger Travel By Rail Type, Scenario, and Region

Low-Power And Non-Motorized Modes Assumptions And Results

Walking is poorly evaluated worldwide due to lack of common definitions and analysis frameworks. Virtually everyone walks daily to help meet their basic needs for some combination of access to food, water, community, work, education, health care, shopping, and recreation. Some of these walk trips are for access to public transportation, or to cars parked near a trip end. Including all short trips, there may be as many as several walk trips a day per person worldwide, making walking the dominant travel mode by trip share. This study, like many, excludes many shorter trips on foot, relying for 2010 data mainly on partial estimates from a few urban travel surveys, since few include an explicit accounting of all foot travel linked to other trips, or even the distances covered in full walking trips. Somewhat more walking trips are assumed in non-OECD than OECD countries, with the most trips per capita in Africa. Baseline walking to 2050 is assumed to be relatively unchanged compared to 2010, though with a slight decline in distance per capita; walking trip share is increased in HS compared to 2010 to reflect the greater possibility for safe, convenient urban walking trips with proper infrastructure and more compact land-use planning.

The most important aspect to improve the walking experience is improved safety, which can be provided through better and much more extensive sidewalks and footpaths, along with safer pedestrian street crossings, slower car traffic in some places, and other measures. These steps may not directly show up as increased walking in some parts of the world, but certainly will provide high value in quality of life and reductions in accident rates.

The HS scenario assumes a dramatic increase in the use of low-power e-bikes and bicycles in countries that don't already have high levels of use. While in the reference case there are high levels of walking in most countries and high levels of biking in a few countries, such as the Netherlands, in HS the walking and biking trips would increase among people with motorized options such as access to cars. Electric bicycles and low-powered electric scooters (collectively called "e-bikes") are in widespread use now only in China, but in HS they would increase worldwide. These are distinguished from high-powered scooters and motorcycles, and, if regulated appropriately, could contribute to slower traffic speeds and safer conditions in areas where they become prevalent. It is important that safety issues associated with fast scooters do not prevent the spread of low-speed, environmentally friendly e-bikes. We hypothesize future ownership and e-bike travel levels that

appear plausible, and average use per day and per year to generate PMT projections. In HS, the increased cycling and e-bike travel serve to offset a large reduction in faster two-wheeler travel to 2050 as part of a push toward greater safety. The results are shown in Figure 11.

Assumptions include:

- Regular bike ownership is explicitly estimated and modeled and follows use patterns that appear consistent with existing literature.[14] Fairly good data exists on bicycle stocks around the world, but average daily use of bicycles is poorly documented. We assume relatively low daily use factors.

- Bike use will rise as investments are made in bike lanes and parking, safety features, and supportive policies, as has happened in various cities[15] and as projected by other modeling. [16] Here it has been assumed that most cities could achieve something approaching average European cycling levels by 2050 but have only a fraction of levels achieved today in Amsterdam or Copenhagen. Much higher shifts for cycling would be plausible with more supportive infrastructure and policy.

- For e-bikes, it is assumed that ownership is currently near zero except in China and parts of Southeast Asia. Growth in ownership and use is based on slowly raising rates, and a complementarity of use between e-bikes and bicycles. In addition, the use of internal combustion engine (ICE) scooters and motorcycles in the High Shift scenario is set to decline with much replacement by e-bikes over the coming 35 years. As a result, total travel via e-bikes and ICE two-wheelers does not grow much on net.

- The total NMT pkm rises for all three modes over time, but more dramatically for e-bikes, with much slower increases for walking and biking.

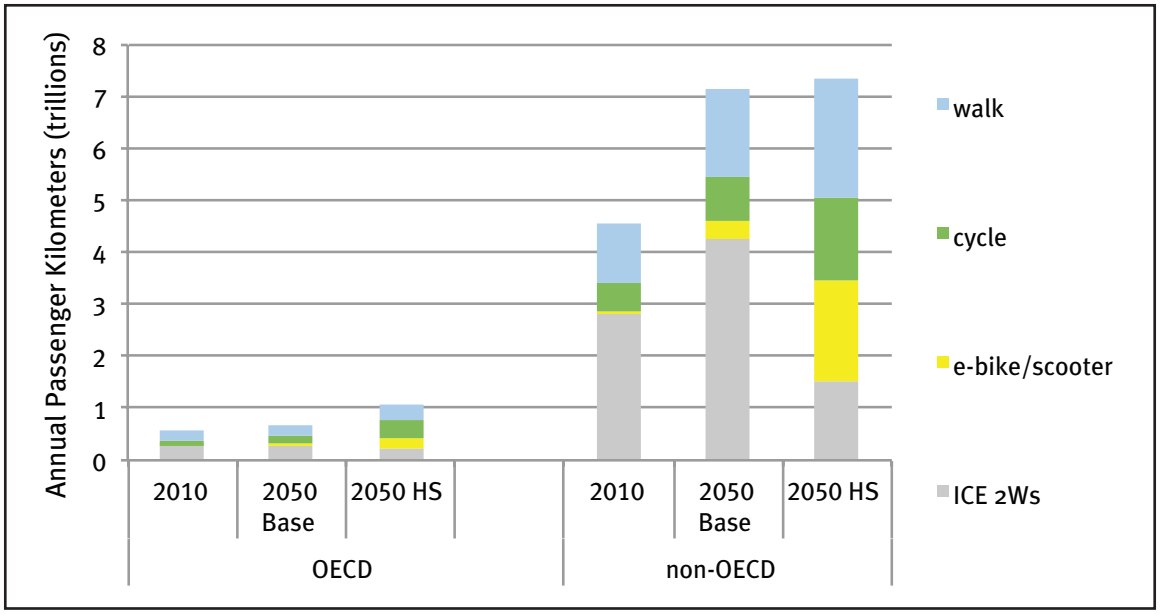


Figure 11: Travel by Non-Motorized and Low Power Modes by Year, Scenario, and Region1

Changes In Car/2-Wheel Travel

As mentioned, a key assumption for the High Shift scenario is that urban vehicle travel is cut by 50% compared to the baseline in 2050 in all regions. Since this is gauged in terms of vehicle kilometers, the stock of vehicles—the number of motor vehicles in use—may change differently if, for example, travel per vehicle changes. This is in fact what happens, as for existing private cars, these are assumed to be left home more often and are thus driven less per year. Thus the sales and stocks of cars in both the OECD and non-OECD regions does not drop by 50%, but by closer to 40%, as shown in Figure 12. This still means far fewer cars and thus far fewer parking requirements, which are assumed to drop proportionately to the numbers of vehicles. Roadway capacity is gauged as a function of vehicle travel, not vehicles. It is assumed to drop in the High Shift scenario somewhat less than the drop in VKT. This is because: a) some roads exist already and are not going to be removed, particularly in the OECD, and b) reducing road construction somewhat less than the change in VKT suggests that there will be less congestion. While congestion reduction is not explicitly measured in this study, it is an economically valuable benefit that likely should not be lost for the sake of full proportionality on reducing road construction.

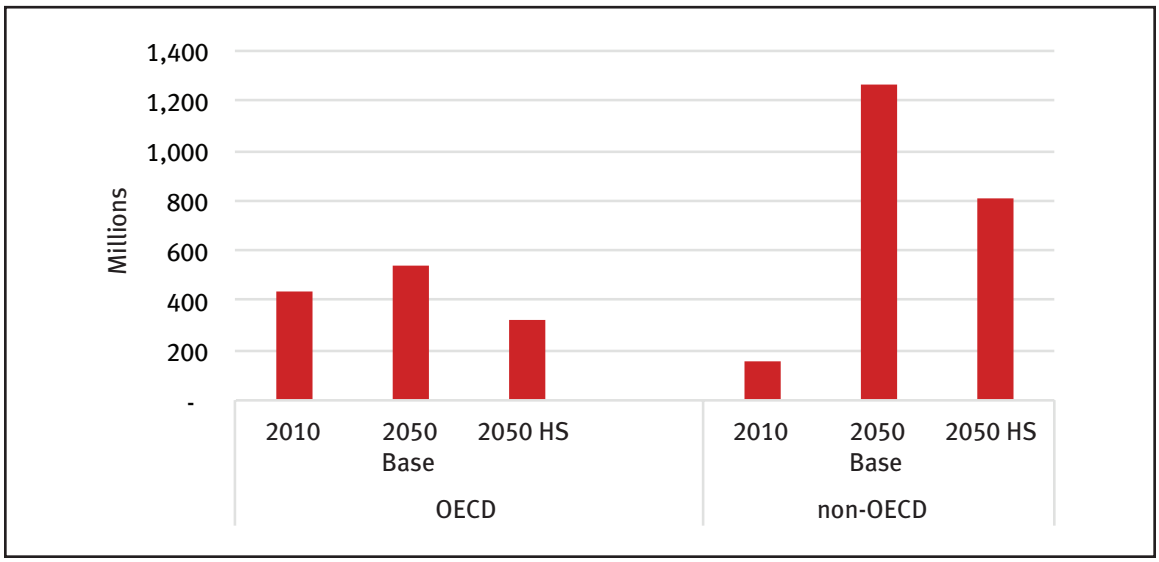


Figure 12: Urban Car Stocks by Region, Year, and Scenario

Another feature of High Shift is that a high occupancy of vehicles is assumed, related to an assumed increase in ride sharing. While the changes are not assumed to be dramatic, they significantly affect mobility—in OECD in High Shift there is 1.6 rather than 1.4 persons per car in 2050, and in non-OECD there is 1.7 versus 1.6 in the baseline in 2050, as shown in Figure 13. This higher occupancy also results in more passenger travel from a given amount of VKT, so vehicle passenger kilometers drops less than vehicle kilometers in High Shift.

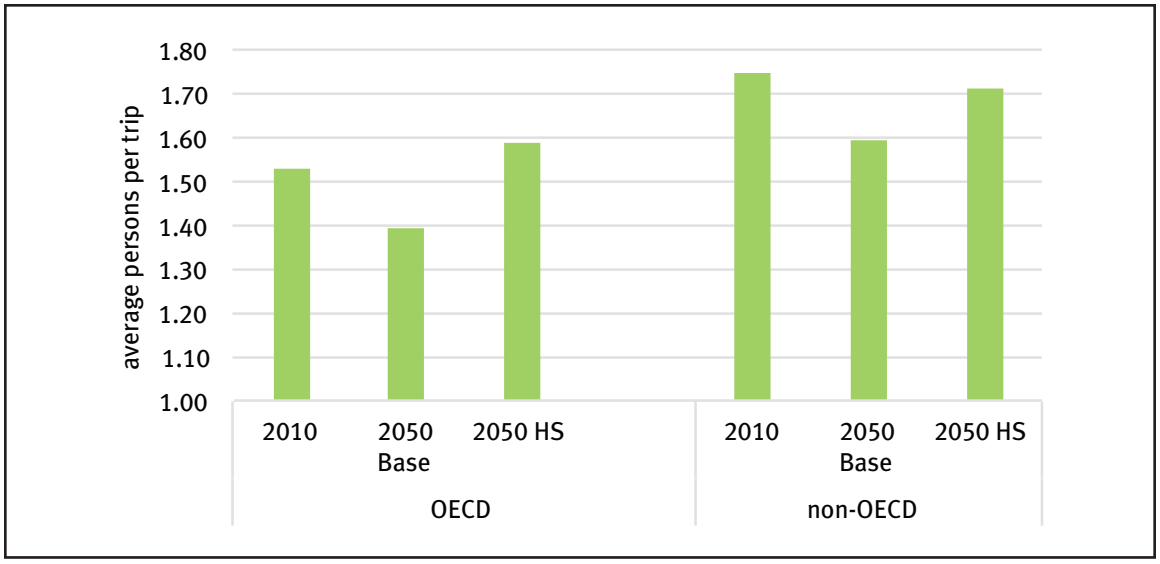


Figure 13: Average load factor (passengers per trip)

These are the main changes in light-duty-vehicle use across the scenarios. The actual characteristics of vehicles is not assumed to change much in HS from the baseline, although there is a slight shift toward smaller vehicles, with slightly better fuel economy as a result. There is also a slight "in-use" fuel economy benefit from reduced congestion on urban roads. In fact, such an effect could be quite large, but a detailed investigation of this and how the traffic reduction in HS could affect it will require further analysis. Additional benefits from fuel economy improvement and the introduction of new technologies such as electric vehicles is also being assessed and will be included in future updates to this study.

Scenario Impacts: Energy and CO_2 Emissions

Since all urban areas in the world are included in the analysis, energy use and CO_2 emissions impacts can be reported at a global and regional level. Energy use is a function of the vehicle travel and vehicle efficiency for each mode, and is calculated taking into account load factors and the number of vehicles and vehicle kilometers needed to move people the specified passenger-kms. Energy efficiency of different types of vehicles (based on MoMo vehicle efficiency estimates, adjusted for urban in-use conditions) varies greatly, but not that much regionally. It does improve significantly over time in the baseline scenario, with identical improvements under the High Shift scenario.

Apart from the levels of travel, the critical assumptions behind the energy use and CO_2 numbers are the efficiency of the vehicles and the ridership on those vehicles. For each region and mode, Figure 14 shows efficiency per passenger kilometer and Figure 15 shows total energy use. Public transit modes are far more efficient than light-duty vehicles, so shifts to these modes cut energy and CO_2 per passenger-km significantly. For transit vehicles, efficiency per passenger-km improves more in HS because ridership per vehicle trip is significantly higher than in the baseline, based on assumed improvements in system management, higher-quality and more frequent services, and urban densification. Cars also become more efficient, as mentioned above, due to fuel economy standards and higher average occupancy.

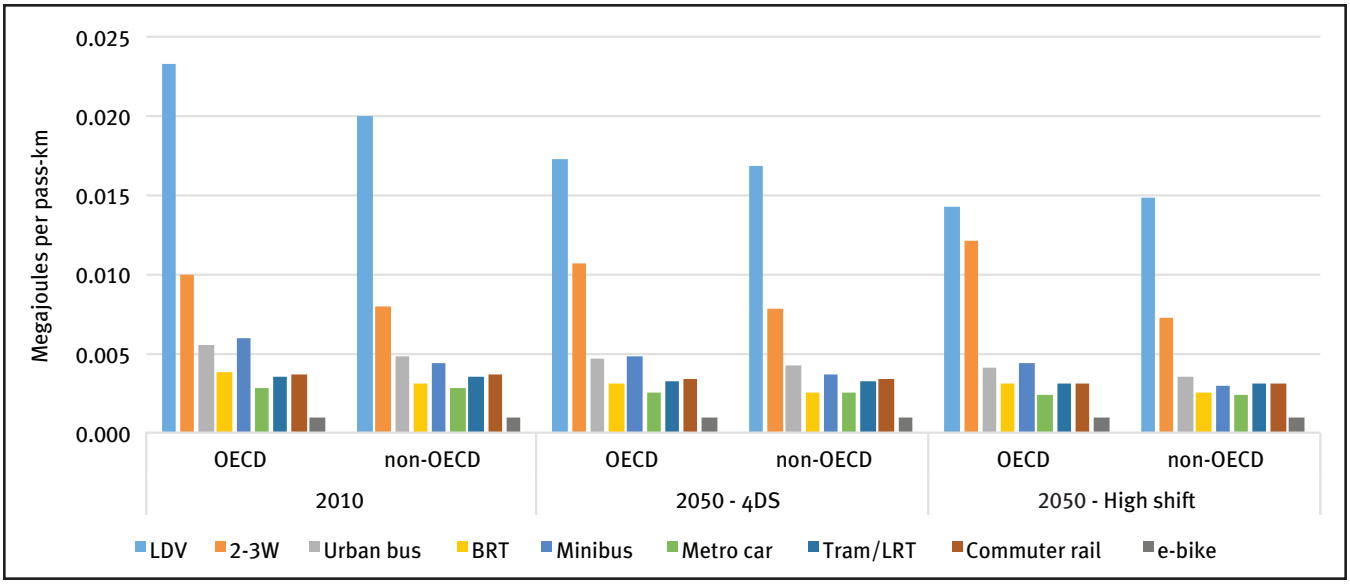


Figure 14: Energy Efficiency by Passenger-Kilometer By Mode by Year and Scenario

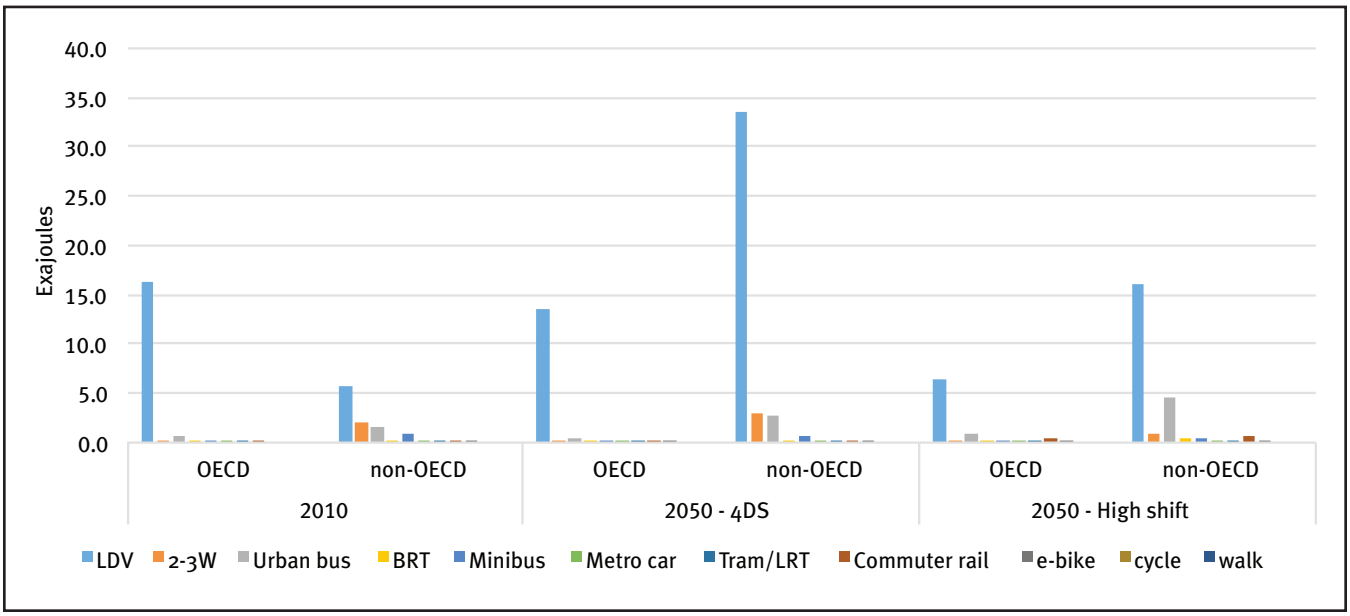


Figure 15: Energy Use by Scenario, Region, and Mode

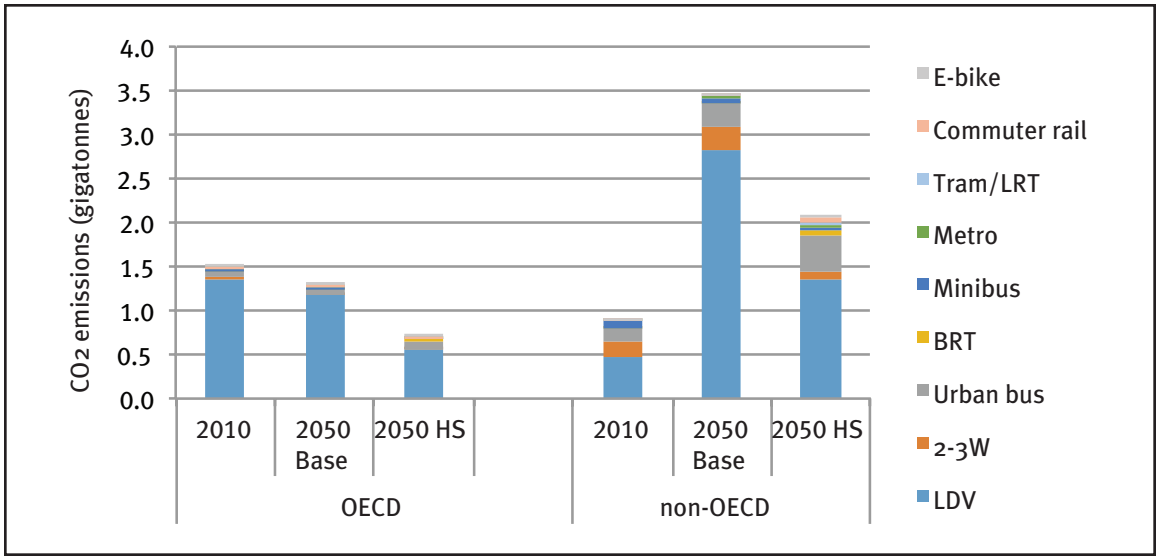


Figure 16: CO_2 Equivalent Emissions from Urban Passenger Transport by Year and Scenario and Mode

The resulting CO_2 emissions by mode are shown in Figure 16. The dominance of light-duty vehicles in current and baseline future energy use and CO_2 emissions is evident, as is the reduction in energy and CO_2 emissions in the High Shift scenario. Compared to the baseline, the High Shift scenario by 2050 would cut global urban passenger land transport CO_2 emissions by 1.7 GT, or about 40 percent, from 4.4 GT in the baseline to 2.7 GT in HS. Specific fuel types are not shown, but road modes are dominated by petroleum fuel while rail modes are almost entirely electrified, as are e-bikes. Electricity generation is decarbonized over time in line with the IEA 4° scenario. This is helpful but not critical for experiencing substantial reductions in CO2 from the High Shift scenario.

It is important to consider that there is significant further greenhouse gas mitigation potential if further fuel economy improvements are added to the mitigation potential of the High Shift scenario. One can and should consider the double-counting effects, which are path-dependent. Indeed, the mitigation potential estimated for "avoid-shift" vehicle-activity-focused strategies vs. technology-focused "improve" strategies depends on which approach is assumed to be the initially applied strategy.

While this study has not focused on further actions to boost motor vehicle fuel economy, it takes into account existing policies that, in the IEA baseline scenario, improve average new car fuel economy by 32% (less energy-intensive) in the OECD and 23% in non-OECD countries. The High Shift scenario increases this to 36% and 27% respectively, due to improved in-use driving conditions and a slight shift to smaller vehicles. However, the Global Fuel Economy Initiative (www.globalfueleconomy.org) calls for much more: a 50% reduction in fuel use per kilometer for light-duty vehicles worldwide by 2030. Achieving the GEFI 2030 goal could reduce 700 megatons of CO_2 annually beyond the 1,700 reduction possible from a High Shift scenario. Taken together, achieving this fuel economy goal with better public transport, walking, and cycling could cut annual urban passenger transport CO_2 emissions in 2050 by 55 percent from what they might otherwise be in 2050 and 10 percent below 2010 levels. Strong fuel economy programs for other types of vehicles (buses, trucks, two-wheelers) could also help, as could vehicle electrification and other low-carbon fuels. These options will be investigated further in relation to High Shifts in the future.

Figure 17 shows CO2 emissions results for HS for major world countries and regions. This shows that by 2050 there are tremendous CO2 savings in rapidly growing economies such as China and India from the High Shift strategy, while there are significant (and proportionately similar) savings in every country and region. In fact, on a percentage basis, the biggest reduction in High Shift relative to both 2010 and to the baseline in 2050 occurs in the United States. Apart from the modal shift effects, this result reflects the fact that the U.S. has the biggest reduction in overall travel in High Shift—about 30% lower than in 2050 baseline. This "avoid" element is large and remains one of the questions this study raises that deserves further investigation.

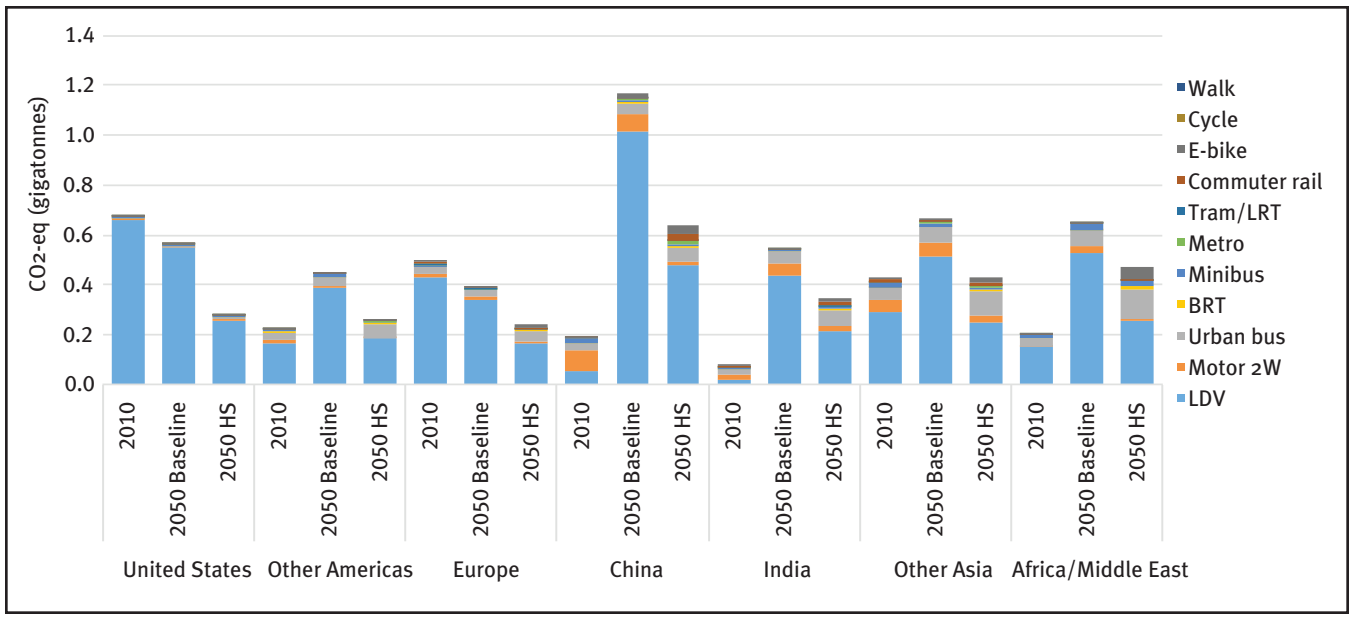


Figure 17: CO2 Equivalent Emissions for Selected Countries

Results: Transit System Infrastructure Requirements

As described above, the system size (and thus infrastructure length) needed to support BRT and urban rail travel was estimated using assumptions of the number and lane-kms of systems in place around the world. These projections were in turn used to develop the infrastructure cost estimates associated with these scenarios, presented below. The total kilometers of system length by region and year for the High Shift scenario is shown in Figure 18. In the OECD, the increase for each mode is significant compared to 2010 but not huge in percentage terms (except for BRT, which is tiny in 2010). In non-OECD countries, the required growth rates are far higher and would require major, sustained investments over the coming decades to achieve. Growth is fastest for BRT and commuter rail.

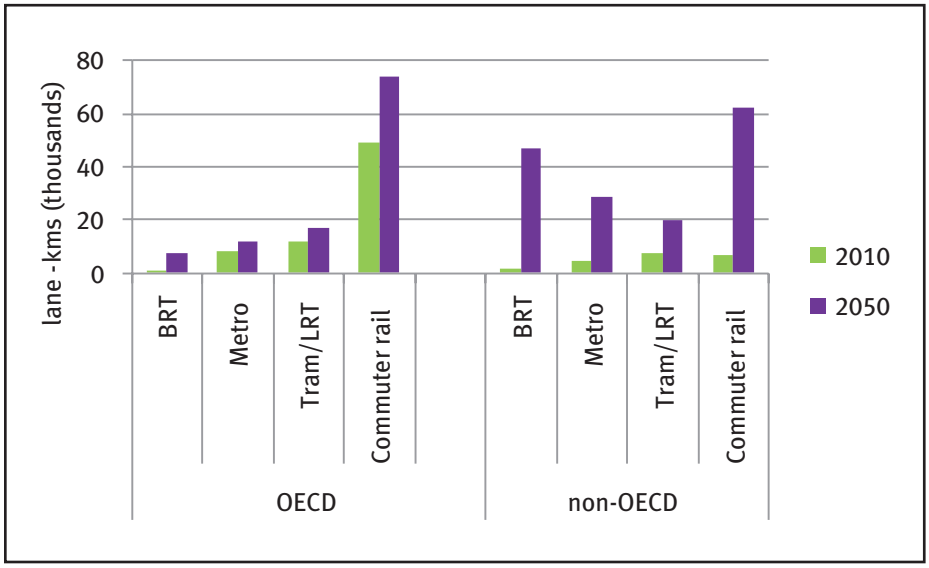


Figure 18: 2010 and 2050 High Shift Rapid Transport System Length by Mode by Region

Results: Cost Implications Of The High Shift Scenario

The major direct cost and investment implications of the High Shift scenario have been estimated, relative to the baseline, from 2010–2050 in a cumulative and annual average fashion, including all market costs to private users and public agencies (i.e., taxpayers):

- Vehicle purchase costs for all types of vehicles, all modes;
- Fuel costs for all modes and vehicle types;
- Vehicle and transit system operating and maintenance cost, including daily O&M costs and infrastructure maintenance costs;
- Infrastructure capital costs, i.e., the one-time investment costs to construct roads, sidewalks, parking lots and structures, and BRT, rail, and bus systems.

These estimates are based on averages from various reports, by country or region.

The cost analysis is summarized in Figure 19. Costs rise as a function of passenger travel growth by mode and region. So, for example, the cost of infrastructure for roads and transit systems rises in proportion to their importance in the two scenarios. Road and parking costs are far lower under HS than in baseline. Transit system construction and operation costs are far higher under HS than baseline. HS has far lower energy requirements and so creates large energy cost savings.

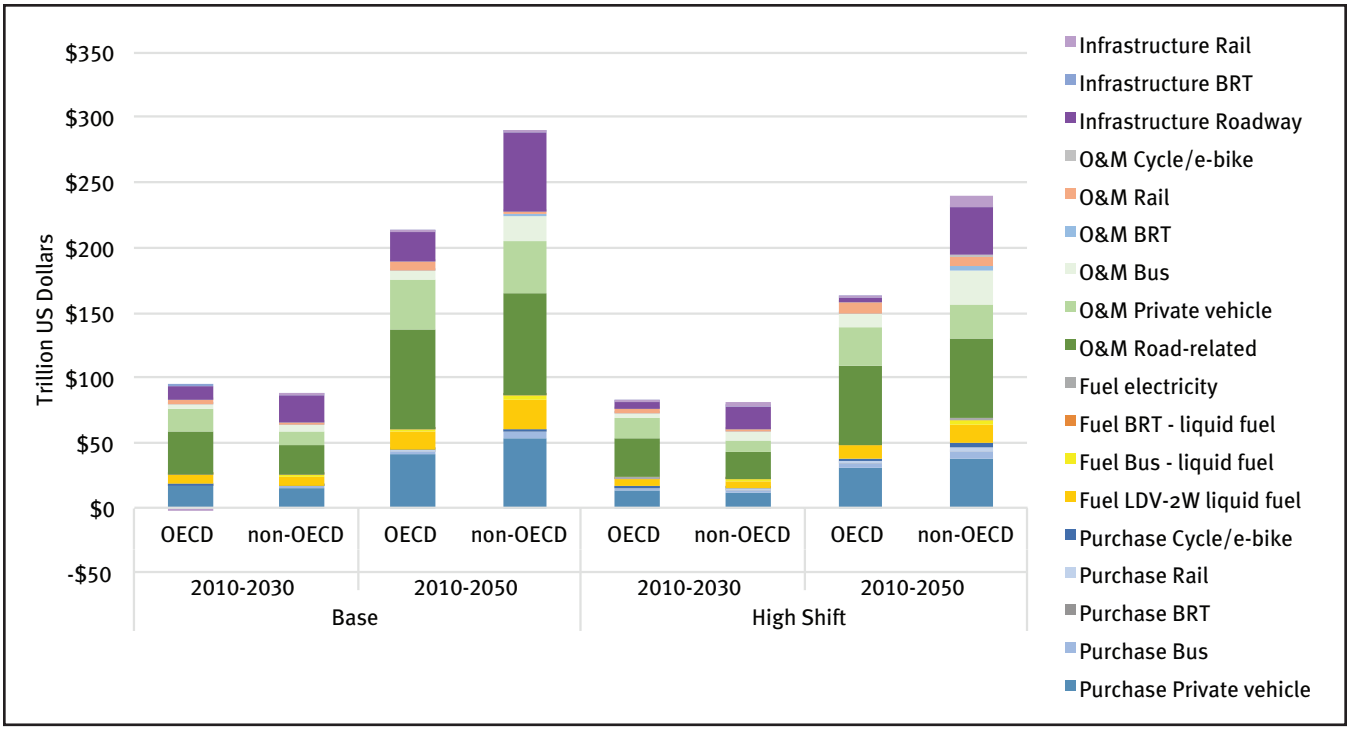


Figure 19: Summary of Cost Estimates 2010-2050 by Type, Scenario, and Mode

Overall, the total costs of the baseline between 2010 and 2050 are roughly $500 trillion ($200T in OECD and $300T in non-OECD), whereas the costs in the HS scenario are about $400 trillion ($160T in OECD and $240T in non-OECD). The HS scenario would trim cumulative costs by approximately US$110 trillion or 22 percent.

Figure 20 breaks out infrastructure investment cost in more detail, and presents this as average annual expenditure to build new infrastructure in the time periods 2010–2030 and 2030–2050. This takes into account the full direct cost per kilometer to build new roads (a function of projected car travel), parking lots (a function of projected car stocks), sidewalks along urban non-highway roads, cycle lanes and paths to handle much of the projected cycling travel, and the specified BRT and rail systems. This, like other costs, is based on current average costs per kilometer in various countries, but is averaged applied at the level of all OECD and all non-OECD given the weakness in much of the data. For example, BRT construction costs are assumed to be $7.5 million/kilometer in non-OECD and twice this in OECD. These costs (and all infrastructure costs) rise over time in real terms, and converge somewhat as incomes and project quality rises in the non-OECD.

The results indicate that in the baseline, infrastructure costs for roads and parking space dominate over all other infrastructure costs. This is because vastly more kilometers of roads (and square kilometers of parking) are built than any type of transit system. However, in HS the number of roads and parking needed drops dramatically, and the costs for rail systems are high enough to be visible in the bars. Yet despite about 25,000 kms of BRT built in the non-OECD between 2030 and 2050, it is barely visible, since the cost is “only” about $12 billion per year, a very small number in the context of other costs in the figure.

It is also worth noting that in the OECD between 2030 and 2050, the infrastructure costs “go negative.” This reflects an actual reduction in the need for roads. In reality it seems unlikely that roads would be removed, but it does suggest a reduction in traffic that would likely provide equal or greater value in the form of reduced traffic congestion on an undiminished road system.

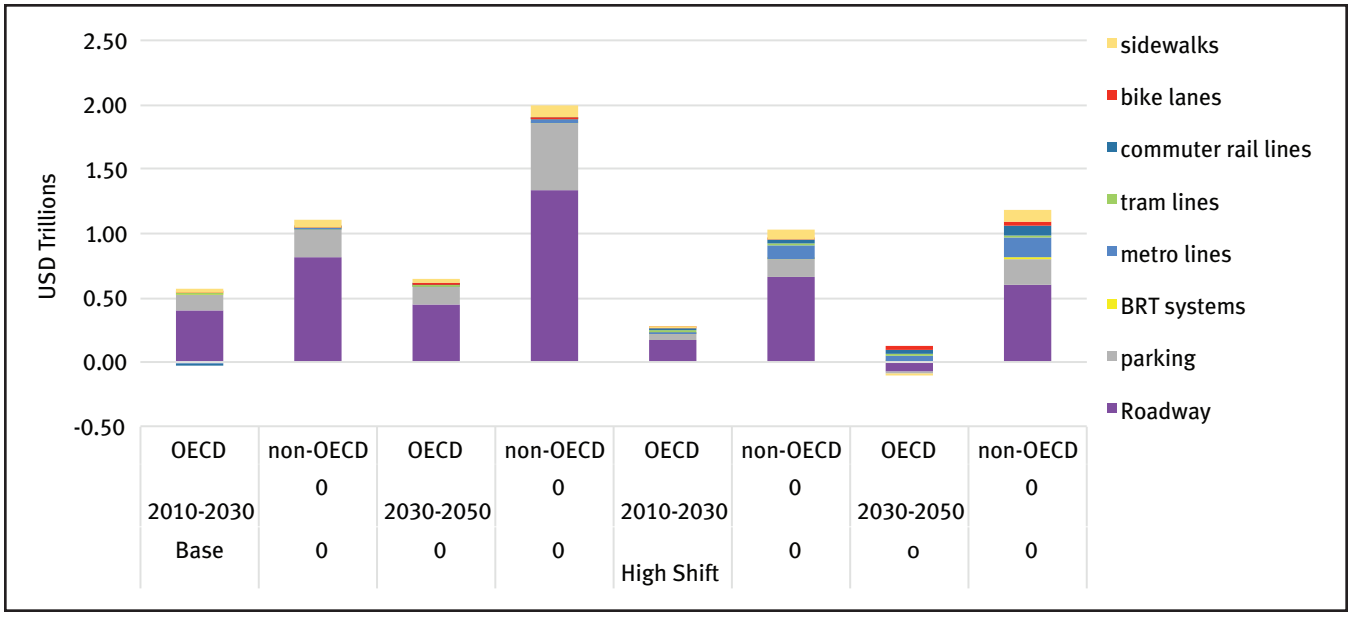


Figure 20: Infrastructure cost estimates, annual averages for 2010-2030 and 2030-2050 by type, scenario and mode

These cost results will be further detailed in a separate documentation report and may be a feature analysis in a future summary report.

Results: Equity Implications Of The High Shift Scenario

In addition to developing an urban version of MoMo, a new demographic breakout of urban travel was developed and linked to this urban projection system. This first-generation "Demographic Equity Economics" model provides the opportunity to track travel by groups within the population. The data foundation for this was a review of 25 national and urban household travel surveys from around the world. This showed that few of the databases (or associated analyses) were directly comparable, using different methodologies, different questions, different group definitions, and different mode classifications for travel. However, data on car ownership by income category was found to be sufficiently comparable to establish approximate base year travel mode shares for a number of regions.[17, 18, 19, 20]

For 2010, passenger travel by mode across income groups sums to total travel on that mode from the broader study; the main uncertainty is how the ridership breaks out across income group going forward in time. Total travel is assumed to be significantly lower for lower-income groups, as suggested in travel surveys, but this difference declines somewhat as the poorest quintiles' income grows. Projections were constructed for 14 regional breakouts by income quintile. Another important cross-check for this projection is that car ownership is a function of the income of each quintile, based on a global income-ownership study.[21] Current income distributions are taken from World Bank data,[22] total income projected in line with OECD projections used in ETP 2012; income breakouts are assumed to retain the same distributional patterns over time (i.e., no changes in GINI coefficient).

Despite uncertainties, the breakout of travel into income groups provides important insights. Compared to 2010, baseline passenger-kms in 2050 about doubles. Much of this is from increases in car ownership among higher-income groups. Under the baseline, as in today's cities, higher auto-centered mobility by upper-income travelers can be expected to result in higher traffic congestion and competition for street space, which degrades the quality of public transport, walking, and cycling that are used by lower-income groups. Under HS, there is much more growth of transit and NMT rather than car growth. As availability of transit and NMT facilities expands and ridership increases, more street space is allocated to lower-income groups than for the cars used mostly by the affluent. Thus, the bottom two quintile groups benefit disproportionately from transit/NMT improvements, as do the top two quintile

groups from increases in car travel infrastructure growth.

In 2010 and even in the 2050 baseline, lower-income groups have relatively low mobility and very low car access, as Figure 21 shows. The vast majority of humanity is unlikely to have access to a car even in 2050. In the HS scenario, there is much more even mobility across groups.

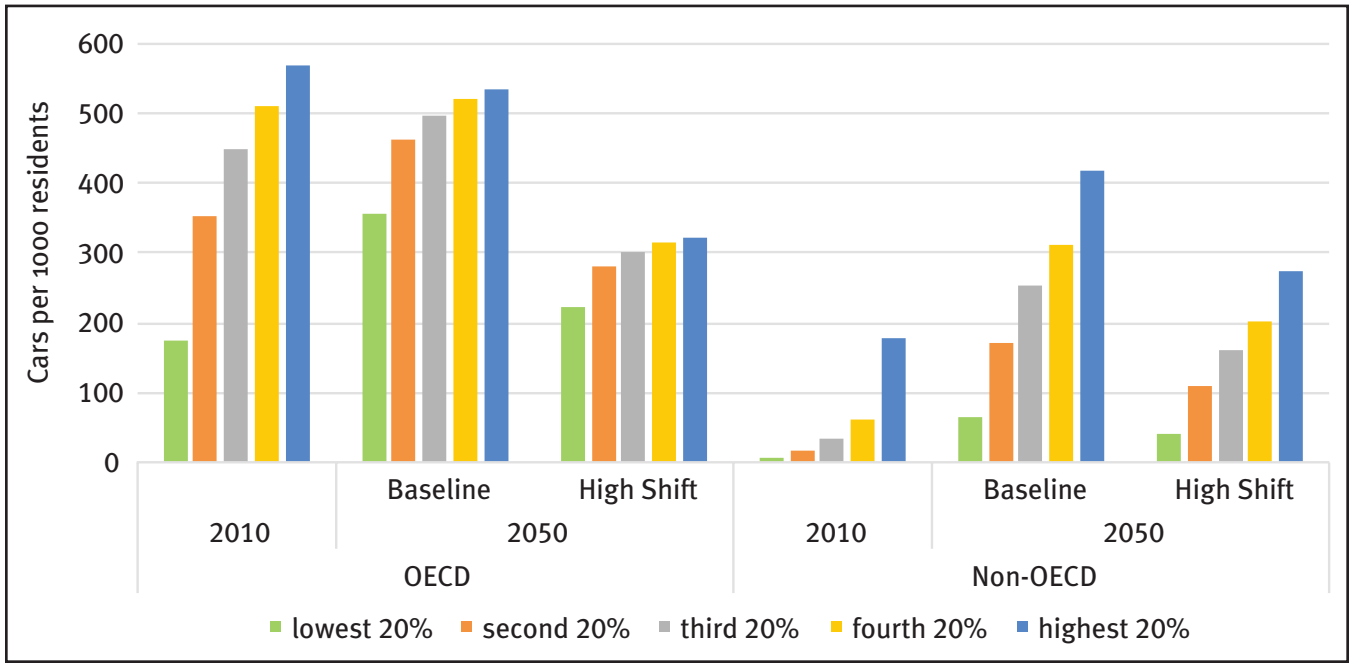


Figure 21: Cars Owned or Used by Income Group 2010 vs. IEA 2050 4DS vs. High Shift Scenario

Figure 22 reflects this rebalancing of travel by mode with a smaller difference in travel per capita in 2050 between the lowest- and highest-income groups under HS compared to the baseline.

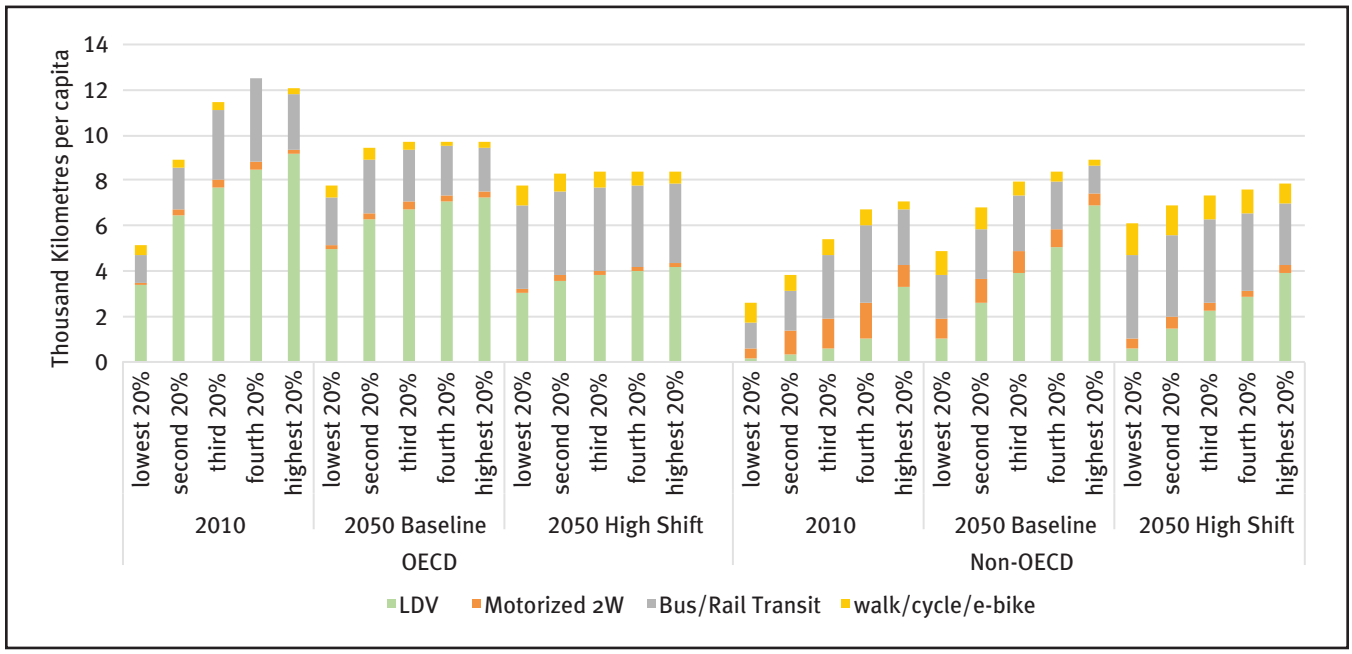


Figure 22: Travel Per Capita by Mode, Income Group, Region, and Scenario

Sensitivity Analysis: High Shift High BRT Scenario

The High Shift scenario represents one of many possible future scenarios. To examine the sensitivity of the findings—especially costs, energy, and CO_2—to changes in some of the input assumptions, a High Shift High BRT scenario was examined. This pivoted off the initial High Shift scenario by holding constant the sum total of commuter rail, metro rail, light rail, and BRT km of service in 2050, but increasing BRT's share of new rapid transit line-kms by half.

Total global BRT and rail-related costs from 2010–2050 are about $33 trillion in the initial High Shift scenario. These costs are $4.4 trillion lower in the High BRT scenario, a drop of 14%. Because there is more BRT to start with in the non-OECD countries and differences in operating and capital costs of transportation between rich and poorer countries, the High BRT scenario offers bigger potential cost savings of $3.7 trillion (from $21 trillion in High Shift) in non-OECD countries compared to 0.7 trillion (from $12 trillion in High Shift) in OECD countries. Energy and CO2 impacts are very similar between the High Shift and High BRT scenario.

Air Pollution And Public Health Impacts

The impacts of various transportation scenarios on air pollution and public health are a function of the characteristics of motor vehicles in use and the manner, location, and amount they are used relative to human settlement patterns. This section examines how different scenarios might affect fine-particle, or soot, pollution ($PM_{2.5}$) and related public health impacts. Further work is needed to evaluate in detail the impacts of other pollutants on health and to consider traffic safety impacts and impacts on health related to levels of physical activity. Because the High Shift scenario would promote greater use of walking and cycling, it would likely reduce premature deaths due to physical inactivity. Reducing vehicle kilometers of travel and increasing the use of active walking and cycling modes might be anticipated to reduce the incidence of road crash fatalities and serious injuries, but more research is needed to support this supposition.

Most government actions to limit the climate impacts of transportation have focused on reducing the volume of fossil fuels consumed by motor vehicles—in particular, gasoline and diesel fuel. Such actions include improving the efficiency of new cars, trucks, and buses; influencing the amount of travel by passenger cars and freight trucks; and improving the efficiency of transportation systems. In addition to impacts on climate and energy consumption, motor vehicles are major contributors to outdoor air pollution, exposure to which is one of the leading causes of premature mortality worldwide.

Governments in the U.S, European Union (EU), and Japan have led the development of regulatory programs to control motor vehicle pollution by setting mandatory limits on emissions from new vehicles and the sulfur content of gasoline and diesel fuel. These international best-practice programs have resulted in new vehicles that are up to 99% cleaner than unregulated vehicles. Many other countries are following the regulatory pathway developed in the EU, which progresses from "Euro 1" to "Euro 6" for cars and light commercial vehicles, and "Euro I" to "Euro VI" for heavy-duty trucks and buses, with Euro 6/VI requiring the cleanest vehicles and fuels.

As part of this study, the International Council on Clean Transportation (ICCT) conducted an analysis of the implications for vehicle air pollution and associated health impacts. Emissions of local air pollutants from on-road vehicles were estimated using the ICCT's Global Transportation Roadmap model. The Roadmap model is an Excel-based tool designed to help policy-makers see trends in transportation activity, energy use, greenhouse gas emissions (GHGs), and local air pollutant emissions; assess the impacts of different policy options; and develop policy roadmaps for clean air and low-carbon transportation.[23, 24] The Roadmap model:

- Estimates fuel life cycle emissions of GHGs (CO_2, CH_4, and N_2O) and local air pollutants ($PM_{2.5}$, NO_x, CO, black carbon, and SO_2), as well as consumption of fossil fuels, biofuels,

electricity, and hydrogen for the years 2000 to 2050;

- Covers passenger cars, light commercial vehicles, buses, motorcycles, three-wheelers, medium- and heavy-duty trucks, passenger and freight rail, passenger aviation, and international shipping;
- Focuses on 11 of the countries/regions with the greatest annual new vehicle sales: the United States, the European Union, China, India, Japan, Brazil, Canada, South Korea, Mexico, Australia, and Russia;
- Considers five aggregate regions consisting of countries in Latin America, non-EU Europe, the Asia-Pacific, Africa, and the Middle East;
- Can be customized to assess transportation trends and policy impacts for specific countries with minimal data requirements;
- Has been reviewed by transportation modeling experts to ensure the validity and adequacy of calculation methods and algorithms;
- Is updated annually, and its outputs are validated against the results of other major national and international transportation emission models.[25]

Four alternative futures were evaluated in the analysis:

- **Baseline-Adopted:** Vehicle activity develops according to the baseline projections, and no new policies are adopted to control motor vehicle pollution.
- **High Shift–Adopted:** Vehicle activity develops according to the High Shift scenario, but no new policies are adopted to control motor vehicle pollution.
- **Baseline–Euro 6/VI:** Vehicle activity develops according to the baseline projections, and most countries adopt best-practice policies to control motor vehicle pollution, equivalent to Euro 6/VI or better.
- **High Shift–Euro 6/VI:** Vehicle activity develops according to the High Shift scenario, and most countries adopt best-practice policies to control motor vehicle pollution, equivalent to Euro 6/VI or better.

The following figures summarize the major differences between these alternative futures with respect to global motor vehicle pollution and associated health impacts in urban areas. Figure 23 summarizes global trends in annual exhaust emissions of primary PM2.5, exposure to which is associated with increased risk of death from cardiopulmonary disease, lung cancer, and acute respiratory infection. While total emissions are forecast to decrease initially as a result of adopted vehicle emissions standards, growth in vehicle activity is forecast to drive net emissions increases under both the "Baseline-Adopted" and "High Shift–Adopted" pathways. While the "High Shift–Adopted" pathway would cut PM2.5 emissions by only 5% in 2050 compared to the "Baseline-Adopted" pathway, the "Baseline-Euro 6/VI" and "High Shift-Euro 6/VI" pathways could cut PM2.5 emissions by 88% to 90%, respectively.

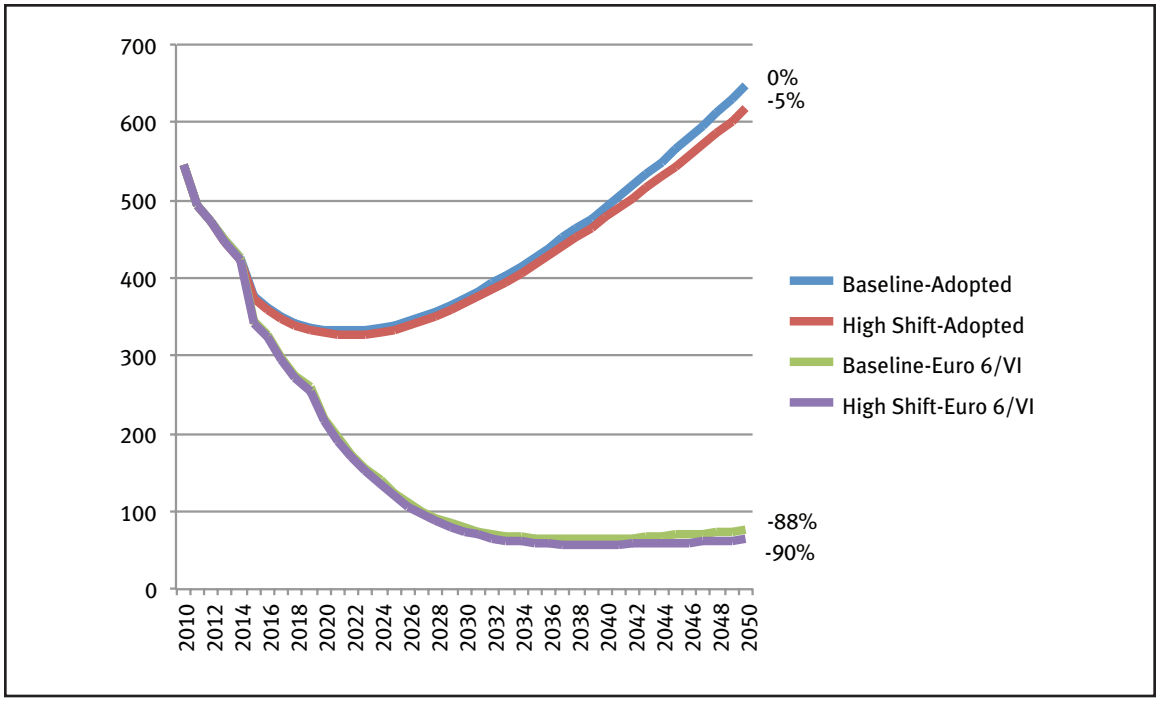


Figure 23 Global Primary PM2.5 Emissions from On-Road Vehicles in Urban Areas, 2010-2050

Figure 24 summarizes global trends in premature mortality resulting from exposure to exhaust emissions of primary PM2.5 in urban areas. The effects of vehicle emissions over time are compounded by increases in urban population and the density of urban areas, both of which contribute to a greater proportion of vehicle emissions being inhaled in 2050 compared to current levels. Under both the "Baseline-Adopted" and "High Shift–Adopted" pathways, the number of premature mortalities could roughly quadruple by 2050. Emission standards requiring vehicle technology and fuels equivalent to Euro 6/VI or better could prevent an estimated 1.36 million premature deaths annually—equivalent to 19 million years of life lost—in 2050.

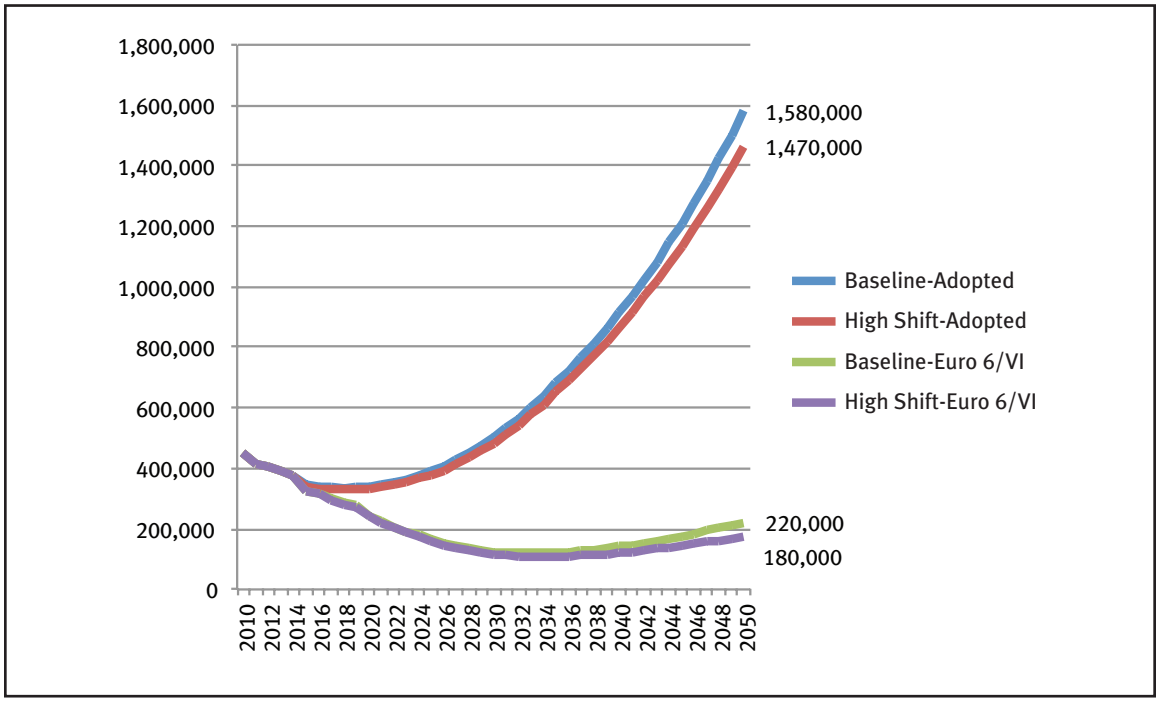


Figure 24: Global Annual Premature Mortalities From Exposure to On-Road Vehicle Primary PM2.5, 2010-2050

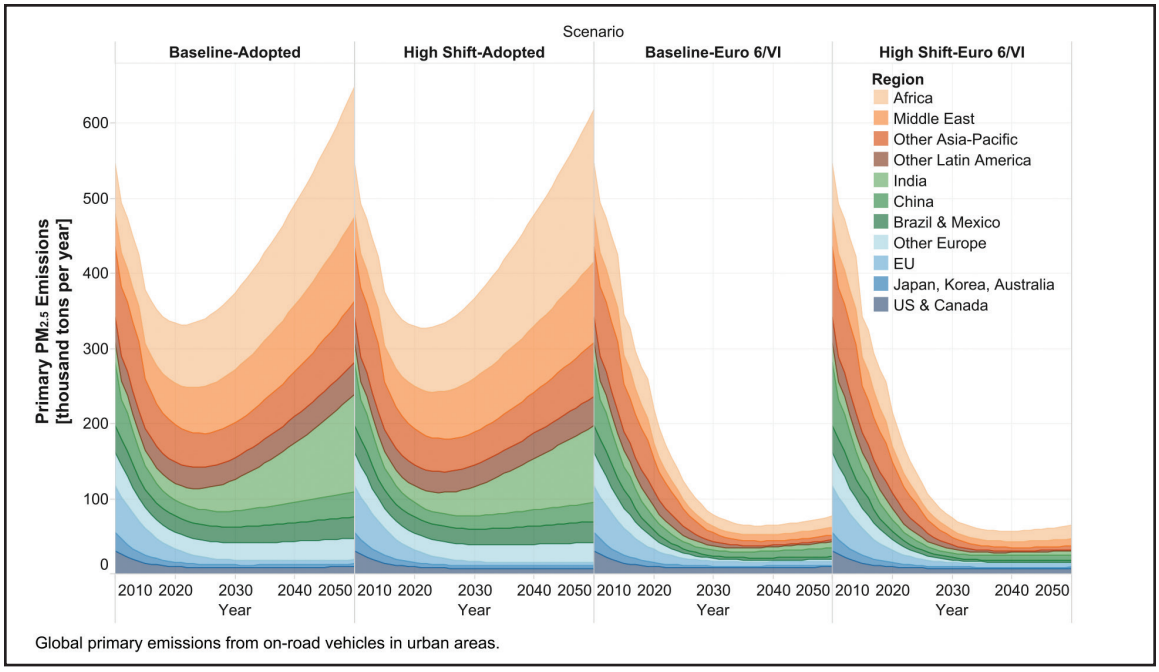


Figure 25: Primary $PM_{2.5}$ Emissions from On-Road Vehicles in Urban Areas by Region, 2010-2050

Figure 25 shows the distribution of PM2.5 emissions under these four alternative futures by region. It shows that regions without advanced emission controls currently account for the bulk of global primary PM2.5 emissions and are forecast to experience sustained growth in vehicle emissions, even as countries with more-stringent vehicle pollution control programs achieve drastic emissions cuts.

The follow-up documentation report for this study will provide greater detail on policies to control motor vehicle pollution along with additional description of the methods and results of the ICCT motor vehicle emissions control analysis. Several key conclusions can be drawn:

- Most regions have not yet adopted best-practice emission controls that can reduce vehicle PM2.5 by 99%. If such regions fail to improve their vehicle emissions control programs, future growth in vehicle activity could produce a four-fold increase in associated early deaths by 2050 even with a global shift to mass transit.

- Expanding the adoption of vehicle pollution control programs equivalent to Euro 6/VI or better could reduce global fleet emissions and associated health impacts on the order of 90% in 2050, equivalent to 1.36 million premature deaths avoided annually. Equipping buses with Euro VI–equivalent emission controls could achieve about 20% of the potential reduction in annual premature deaths.

- Diesel vehicles at early stages of emission control have very high PM2.5 emissions compared to gasoline vehicles. Commercial vehicles, many of which are powered by diesel, account for over 80% of global PM emissions but only 20% of vehicle activity.

- At the global level in 2010, the average bus emitted nearly 50 times the PM2.5 per vehicle-km as the average passenger car. Shifting passenger travel from passenger cars to buses needs to be accompanied with Euro VI–equivalent emission controls for buses to have significant air-quality benefits.

- Once vehicles are equipped with best-practice emissions controls, policies to limit growth in vehicle activity consistent with the High Shift scenario could avoid an additional 40,000 annual premature deaths caused by exposure to vehicle emissions in 2050.

- Where adequate clean diesel (fewer than 50 parts per million sulfur) is available, Euro VI–equivalent technologies have been found to add $3,200 to $6,400 to the cost of new buses compared to Euro III–equivalent controls. [26, 27, 28] These costs are modest relative to the capital cost of new buses.

Conclusions And Next Steps

Given the assumptions made and scenarios compared, the main finding is that a high-transit, high-non-motorized-vehicle scenario that (at least in the developing world) provides similar total mobility (in passenger kilometers) as a baseline, more car-dominated scenario is likely to be more equitable, to be less expensive to construct and operate over the next 40 years, and to sharply reduce CO2 emissions. Unmanaged growth in motor vehicle use threatens to exacerbate growing income inequality and environmental ills, while more sustainable transport delivers access for all, reducing these ills. This report's findings should help support wider agreement on climate policy, where costs and equity of the cleanup burden between rich and poor countries are key issues.

This scenario is one example of many possible futures. It is not a prediction and may be extremely challenging to achieve, requiring high rates of public investment. A principal purpose is to use this scenario as the basis to investigate the implications of this future for a range of impacts and indicators of interest. Is high-quality mobility and access preserved? What might be the safety and non-air-pollution-related health impacts? What might the impacts of this future be for public finance, job creation, and economic well-being and overall sustainable development? These aspects are being further investigated.

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