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Transportation

in Developing Countries

An Overview of Greenhouse Gas Reduction Strategies

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CALIFORNIA, DAVIS



PEW CENTER
ON
Global CLIMATE
CHANGE

Transportation

in Developing Countries

An Overview of Greenhouse Gas Reduction Strategies

Prepared for the Pew Center on Global Climate Change

by

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Deborah Salon

UNIVERSITY OF
CALIFORNIA, DAVIS

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Foreword *Eileen Claussen, President, Pew Center on Global Climate Change*

This report focuses on transportation in developing countries, where economic and social development — not climate change mitigation — are the top priorities. Yet decisions on infrastructure, vehicle and fuel technologies, and transportation mode mix are being made now that will significantly affect greenhouse gas (GHG) emissions for decades. The key is to identify strategies that address high-priority local issues while also reducing GHGs. There are many such options but no “one-size-fits-all” approach. Thus building the capacity of local institutions is especially critical.

Vehicle ownership rates in developing nations are low compared to wealthy ones, but lead to far worse traffic congestion and air pollution. Motorization is skyrocketing and populations increasing, stretching limited infrastructure and institutional capacity. Despite these challenges, there are many opportunities for improvement. Some have worked in the past; others could leapfrog over some of the costly and environmentally damaging paths taken by developed countries.

This overview is part of a five-report series on transportation in developing countries and draws on the four other reports on specific cities and countries. The case studies were researched and co-authored with experts from Chile, China, India, and South Africa, and estimated high and low projections of transportation emissions in 2020 compared to 2000. The case studies’ key findings include:

- *Rapid growth in transportation GHG emissions is unavoidable in most developing countries.* The 2020 low emission scenarios in the four case studies showed only one decrease —12 percent in South Africa — and up to a quadrupling in Shanghai, China. The high scenarios ranged from an 82 percent increase in South Africa to a sevenfold increase in Shanghai.
- *Delhi, India.* Delhi demonstrates that personal mobility can be achieved at relatively low incomes — but at a high economic, environmental, and social cost. With an average income of \$800 per capita, Delhi has 200 motor vehicles (mostly motorbikes) per thousand people while Chile has an average income of \$5,000 and only 100 motor vehicles per thousand (mostly cars). Delhi’s promotion of more efficient vehicle engines will go a long way in restraining emissions.
- *Shanghai, China.* After years of deferred investment, Shanghai invested billions in its transportation infrastructure in the 1990s, balancing investments in roads and transit, integrating transportation and land use planning, and restraining vehicle ownership. But rapid economic growth, planned decentralization of this very dense city, and auto industry promotion will accelerate increases in motorization, energy use, and GHGs. “Intelligent transportation systems” and leapfrog technologies such as roads built for minicars are among Shanghai’s options to restrain its emissions.
- *Chile.* Chile is one of the world’s most sophisticated at transferring transportation infrastructure and services provision to the private sector and could pioneer market-based approaches to transportation and environmental challenges. Examples include the sale of operating concessions, implementing vehicle fees during rush hour travel, and adjusting parking fees according to trip purpose and length of stay.
- *South Africa.* South Africa has very high per capita vehicle ownership and GHG emissions for its income due to reliance on carbon-intensive synthetic fuels, protected vehicle manufacturing, subsidies for company cars, and land use patterns that are a legacy of the country’s past apartheid policies. The Clean Development Mechanism could be used to finance climate-friendly improvements such as switching to less carbon-intensive feedstock in synthetic fuel production.

The Pew Center gratefully acknowledges Ralph Gakenheimer of MIT and Michael Walsh, an independent transportation expert, for their reviews of earlier drafts.

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Executive Summary

Worldwide, greenhouse gas emissions are rising faster in transportation than in any other sector. Rapid motorization — more cars and trucks — is the principal cause. This report focuses on the challenges faced by developing countries in accommodating and managing motorization and the demand for improved transportation.

Enhanced mobility has many positive effects on economic development and social welfare, including more efficient movement of goods and improved access to jobs, health services, and education. However, if enhanced mobility is achieved primarily through increased reliance on conventional private cars, it can mean diverting substantial financial resources to roads and suffering worse air pollution and traffic congestion. The benefits are enormous, but the costs can also be substantial. These positives and negatives are accentuated in the developing nations of Africa, Asia, and Latin America. Most are experiencing rapid population growth and urbanization, and many have fast-growing economies. The number of private vehicles is increasing in almost all developing countries.

The challenges posed by motorization are unprecedented for these countries. When the more developed countries were building their transportation infrastructure, their populations were small compared to those in much of today's developing world, and the cost of motorized vehicles was relatively high. Today's megacities of the developing world are already huge and still expanding. There is little time or money to build public transportation systems or to expand roads to handle the new traffic. They are already experiencing serious congestion, economic and environmental damage, and major safety problems. Yet the problems are not uniform; each city and country faces different circumstances.

This report provides a broad characterization of transportation in developing countries, identifying common challenges and opportunities for policymakers, and suggesting policy options that aim to slow the growth of greenhouse gas emissions from the transportation sector.



The most important observations of this report are the following:

- *Rapid motorization — and rapid growth in transportation-related greenhouse gas emissions — are unavoidable in most developing nations.* Most developing countries today have low per capita transportation emissions, largely because few people have access to personal transportation. Rapid motorization is transforming transportation and accelerating increases in greenhouse gas emissions.
- *The relationship between car ownership and income is not fixed.* While it is true that income is the primary force of motorization — explaining perhaps half the growth in vehicle ownership — there is much variation in vehicle ownership among cities and countries at similar income levels.
- *Once people have personal vehicles, they use them even if alternative transportation modes are available.* This is because the variable cost of operating a vehicle is relatively low compared to the fixed cost of purchasing one.
- *There are many sensible policies and strategies that would slow the growth of transportation sector greenhouse gas emissions.* Key strategies include increasing the relative cost of using conventional private cars and enhancing the quality and choices of alternative transportation modes.
- *Many of the strategies for slowing and eventually reducing greenhouse gas emissions from transportation have local as well as global benefits.* Local benefits include reduced air pollution, less traffic congestion, and lower expenditures for road infrastructure.

This report explores strategic paths and alternative futures that could break the link between economic and greenhouse gas emission growth in developing countries. Successful efforts underway in some developing countries — examples of which are highlighted in some of the case study reports that contributed to this overview — demonstrate that developing countries can forge a more sustainable transportation future. Is there a single city that can be looked to as a model for others? This report suggests that the answer is “no.” There are cities and countries that have embraced innovative and effective strategies, but none represents a universally applicable model or pathway.

Energy use and carbon emissions around the globe are increasing faster in transportation than in any other sector, and transportation emissions are increasing fastest of all in developing countries. This report does not suggest that developing nations should adopt entirely different transportation systems than currently operate in more developed countries. There is no perfect solution or leapfrog technology at hand. The reality is that most transportation modes and technologies are already being used internationally. The fundamental desire for personal transportation, and for greater mobility at lower cost, is universal. It is neither realistic nor fair to ask those in the developing world to deprive themselves of the things they need and want, from meeting their basic transportation needs to having access to cars.

Instead, this report suggests that developing countries can choose a more sustainable growth path. They can learn from the experiences of industrialized countries in crafting integrated land use and transportation plans, encouraging more efficient forms of vehicle ownership and use, and accelerating the introduction of environmentally sensible vehicle technologies and fuels. Indeed, as a 1996 U.S. National Academy of Sciences report concluded, “greater reliance on nonpolluting modes of transportation in developing-country cities, coupled with the strong integration of residential and economic activities, suggests those cities may be in a position to avoid some of the most costly mistakes of transportation investment in the industrialized countries.”¹

However, the economies and populations of many of these cities are growing at unprecedented rates and personal vehicles are often available to people with very low incomes. Policy and investment decisions with far-reaching implications must be made quickly, or the consequences could be catastrophic — economically, environmentally, and socially. But even with the greatest sophistication and best managers, the choices are not obvious. Simply replicating the choices of other cities in most cases would be ineffective. The elements of a successful transportation strategy are likely to vary greatly depending on local circumstances and institutional strengths and weaknesses.

Without new measures, greenhouse gas emissions from transportation in the developing world will exceed those in the industrialized world sometime after 2010. While the need to limit greenhouse gas emissions may not be a driving force for developing countries in the foreseeable future, many of the strategies that could reduce greenhouse gas emissions would also address the more immediate problems of local air pollution, access to basic transportation, and infrastructure financing pressures. This report focuses on strategies and policies that not only slow the growth of greenhouse gas emissions, but also help achieve local priorities.

Box 1

About the Transportation in Developing Countries Report Series

This overview report draws on four case studies in two cities — Delhi, India and Shanghai, China — and two countries — Chile and South Africa. The case studies were prepared by an international research team led by Professor Daniel Sperling and the Institute of Transportation Studies (ITS) at the University of California, Davis. They are published as separate Pew Center reports co-authored by Dr. Sperling and Dr. Mark Delucchi, also of ITS, and:

Delhi, India:

Ranjan Bose and K.S. Nesamani, Tata Energy Research Institute (TERI), New Delhi
Geetam Tiwari, Indian Institute of Technology, New Delhi

Lee Schipper, International Energy Agency
Lorien Redmond, University of California, Davis

Shanghai, China:

Hongchang Zhou, Tongji University, Shanghai
Deborah Salon, University of California, Davis

Chile:

Raúl O’Ryan, Universidad de Chile, Santiago
Tom Turrentine, University of California, Davis

South Africa:

Jolanda Pretorius Prozzi,
Cambridge Systematics, Oakland, California
Clifford Naudé, Council for Scientific and Industrial
Research: Transportek, Pretoria

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Transportation In Developing Countries

I. Introduction

Vehicle ownership is soaring in most major cities in developing countries, leading to rapid increases in transportation energy use and greenhouse gas (GHG) emissions. Rising GHG emissions are one of several adverse side effects of motorization.

Transportation plays a central role in economic, social, and environmental development. The goal of transportation is to move goods and passengers efficiently, while limiting negative impacts on the environment and society. Although simple to state, the goal is difficult to achieve. It requires a variety of organizations and institutions in the public and private sectors and at the local, regional, national, and sometimes even international levels to operate in concert. It requires continuous balancing of desires and needs within the context of existing institutions and shifting political and economic interests. Pragmatically speaking, it requires finding the appropriate mix of private and public transportation.

The pivotal issue is motorization. The desire for personal vehicles is powerful and pervasive. Personal vehicles, from scooters to large company cars, provide a high level of access to goods, services, and activities, along with unmatched freedom and flexibility. For many, cars and light trucks are also valued as status symbols and as secure and private means of travel. For businesses, these vehicles are an efficient means of increasing productivity. Vehicle ownership, size, usage, and energy consumption are increasing almost everywhere in the world.²

Vehicle ownership is pivotal for a variety of reasons. A study by the U.S. National Academy of Sciences asserts, “With very few exceptions, rapid growth in demand for motorized transport has swamped transport [infrastructure] capacity in the cities of the developing world.”³ Many cities in developing countries are experiencing stifling traffic congestion,⁴ and most are not able to build enough road infrastructure to keep pace with vehicle demand.⁵ Ralph Gakenheimer of MIT asserts that “mobility and accessibility are declining rapidly in most of the developing world,”⁶ despite increasing motorization and road building.

Energy use is increasing faster in the transportation sector than any other sector, and fastest of all in developing countries. Transportation energy use in developing countries has been increasing at over 4 percent per year over the past 20 years, far exceeding the global 2.7 percent rate of increase.⁷ Because virtually all this energy is in the form of petroleum, increases in transportation energy use translate into large carbon emissions increases. A recent report by the World Bank projected carbon emissions from transportation would increase three times faster in developing than in developed countries between 1986 and 2010.⁸

Motorization not only greatly expands energy use and the need for more road space, it also transforms lifestyles in both positive and negative ways and places much greater stress on the environment. The energy and GHG challenge is just the tip of the iceberg. The larger challenge for developing nations is to devise strategies that increase mobility for broad segments of the population at an affordable price without causing major environmental problems.

The goal of this report is to identify policy instruments and investment strategies that slow the growth of transportation-related GHG emissions from developing countries. Because controlling GHG emissions is a low priority in most of the developing world, recommendations are framed in the context of economic, social, and environmental goals. For economic as well as environmental reasons, developing countries need to examine alternatives to the car-centric development and investment patterns that prevail in most of the industrialized world. Yet people everywhere value the benefits of owning personal vehicles. Thus, this report explores opportunities to make personal transportation available in the most economically, environmentally, and socially sustainable manner possible.

As part of this series of reports on transportation in developing countries, studies were conducted of two metropolitan regions (Delhi, India and Shanghai, China) and two nations (Chile and South Africa). These regions represent a range of political systems, institutional capacities, population densities, vehicle ownership rates, income levels, transportation modes, and energy consumption characteristics. The authors conducted extensive interviews with government officials, academics, and industry representatives in each country. This approach was chosen, rather than a more quantitative modeling approach, because data are sparse and often unreliable, and it is difficult to predict the quantitative effect of specific policies on carbon emissions. The authors used the case studies to generate insights and evidence for a range of policy choices.

These choices, elaborated upon later in this report, have a significant effect on lifestyle, economic and industrial development, and environmental quality. Although GHG emissions in most developing countries will increase due to economic growth, tailored policy measures can restrain these increases. A combination of technological and behavioral changes is required to pursue a more economically, socially, and environmentally beneficial path.

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II. The Transportation Picture

The challenges for developing cities are daunting and the opportunities vast — far more than was the case for cities such as London, New York, Paris, and Tokyo.

Cities in the developing world are expanding at unprecedented rates. More people with more purchasing power demand more and higher quality transportation services. Motorization is often the answer, especially as vehicle technology improves and vehicle costs decline. A parallel phenomenon with freight trucks translates into further demand for vehicle travel, roads, and space.

Rapid motorization is creating major challenges in the expanding “megacities” of the developing world. These cities face stifling traffic congestion, huge expenses for road infrastructure and worsening air pollution. Many have much more severe traffic congestion and air pollution than U.S. cities. Bangkok, Thailand is the best known example, but there are numerous others. What is surprising and troubling is that these car-induced problems occur even though vehicle ownership rates are still far lower than those in more developed cities (see Table 1).

Table 1

Cars Per Thousand Inhabitants in Seven Cities

City	Population	Cars Per Thousand Inhabitants
Santiago	5,500,000	129*
Shanghai	13,000,000	22*
Delhi	13,418,000	63*
London	6,852,000	340**
New York City	7,497,000	230**
Tokyo	8,164,000	210**
Paris	8,791,000	340**

Sources: Authors' research, and Focas, Caralampo, ed. 1998. *The Four World Cities Transportation Study*. London Research Center.

*1998-2000

**1990

The difference between the earlier challenges faced by major cities in developed countries and current challenges faced by the expanding megacities of the developing world stems largely from the timing of the development process. When the more developed countries were building their transportation infrastructure, their populations were small compared to those of the developing world today, and motorized vehicles were less affordable.

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+ **Transportation** In Developing Countries

Developed cities were able to start with small, gradual infrastructure investments. Today, developing countries are forced to invest massive sums in new infrastructure to handle soaring passenger and freight traffic. In most cities, there is no time for small-scale experimentation.

On a positive note, the timing of rapid transportation expansion in developing countries today has three significant advantages. First, earlier successes and failures in developed and developing countries present examples from which to learn. Second, much more varied transportation technology options exist now than ever before. Third, even modest changes will have large impacts in as little as ten years.

A. Transition to a Motorized Transportation System

Although there is tremendous diversity among cities in developing countries in terms of their transportation needs and existing systems, they face common challenges. One particularly difficult challenge is to produce a smooth transition from a largely non-motorized transportation system to one that is motorized. The vast majority of the world still does not have access to personal vehicles, and a large proportion does not even have access to motorized transit services.

“[Thirty-three] percent of China’s population and 75 percent of Ethiopia’s population still do not have access to all-weather transport. Walking more than 10 km per day each way to farms, schools, and clinics is not unusual in rural areas, particularly in Sub-Saharan Africa, but also in parts of Asia and Latin America. ...Commuting by public transport is very costly for the urban poor, taking, for example, 14 percent of the income of the poor in Manila compared with 7 percent of the income of the non-poor.”⁹

Most big cities in developing countries have evolved largely without motorized vehicles. Roads are often narrow and without sidewalks. Densely packed housing, businesses, and industrial buildings leave no room for roads to be widened. This land use pattern works well for societies that rely largely on non-motorized transportation modes. People do not have to travel far to gain access to goods and services. Each person traveling takes up relatively little roadway space, and travel is generally low-speed and safe, even for pedestrians. Now, however, the automobile population is growing quickly, creating exceptional stress.¹⁰

Motorized personal vehicles are highly attractive. They are less physically taxing than other modes of travel, often offer better protection from the weather, and have the capacity to carry extra cargo. But they also impose high costs.

The infrastructure cost to accommodate these vehicles and to convert an urban area to large-scale motor vehicle-based transportation is enormous. Freeways, already common in most large cities of the developing world, require large swaths of land, and even local streets must be widened to accommodate motorized vehicles and to separate them from non-motorized travelers.

The cost is not just economic. Leveling neighborhoods to make room for new roadways disrupts communities. It is now widely recognized that the partitioning and devastation of neighborhoods in U.S. cities in the 1950s and 1960s to make way for urban freeways contributed to social decline; only now are many of these neighborhoods recovering. In many developing cities, political opposition to infrastructure investments that displace residents — similar to the “freeway revolts” in San Francisco and Boston — may make them increasingly difficult to implement.¹¹

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Social disruption results not just from neighborhood fragmentation, but also from the increasing disparity between who bears the costs and who reaps the benefits. Many of the poorest cannot afford even to ride buses. Others often pay 30 percent of their income for transportation to get to work. At the other end of the spectrum are a growing upper and middle class that can afford inexpensive personal vehicles (including mopeds,¹² scooters, and cars), but may resist paying the cost of new infrastructure (through taxes and fees). Thus, government is burdened with large transit subsidies to the poor and road subsidies for all. Meanwhile, more highway capacity will mostly benefit the most affluent while bringing more congestion, noise, and pollution to the masses.¹³

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Financing infrastructure development is no small feat. Road construction is extremely expensive. Some areas have opted for privatization of new roadways and other transportation infrastructure as a means of avoiding shortcomings in public financing. In Chile, for example, the government began a public works franchising program in 1991. In this program, private firms build, finance, and maintain a piece of infrastructure. The companies are allowed to collect user fees (i.e., tolls) for a specified period of time to cover the cost of construction, operation, and maintenance, and to earn a profit. Today, all of Chile’s main interurban highways are built and operated by private companies under franchises. Urban roads have yet to be franchised, but Chile is exploring that option.

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Transportation In Developing Countries

One option to reduce the need for new roadway infrastructure is to improve the efficiency of existing roadways. According to the World Bank,

“Sophisticated coordination of traffic signaling can increase effective road capacity by as much as 30 percent and increase speeds to levels at which emissions per vehicle-mile¹⁴ are much lower.... In practice, however, implementation has often been handicapped by weak or non-existent enforcement and by staff who are inadequately trained to design and maintain systems.”¹⁵

In addition to road siting and financing challenges associated with the transition from non-motorized to motorized transportation systems, the coexistence of the two systems and the large number of vehicle types in many of today’s developing cities poses special problems. Safety is a major issue in many locales. In Delhi, pedestrians, bullock-drawn carts, three-wheeled rickshaws, luxury cars, and tractor-trailers all share the same roadways. The roadway fatality rate is high by global standards — especially for pedestrians, since many Delhi streets do not have sidewalks.

Some cities have coped better. For instance, Shanghai has built grade-separated lanes for bicycles and slow-moving scooters along most major roads, and separate sidewalks for pedestrian traffic. Because cities in Latin America do not have as wide a variety of vehicle types on the roads, traffic management there is not as difficult.

Contributing to the overall challenge of adapting a transportation system to changing circumstances is the rate of change. Populations, city areas, and incomes are growing rapidly in many developing cities, often at rates exceeding 10 percent per year. These cities are spreading across the landscape, following the same suburbanization and decentralization land use patterns as more affluent cities in developed countries.¹⁶ The population of almost all

Figure 1

A Street in Delhi, India



Photo by Lorien Redmond, University of California, Davis. 2000.

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developing cities is soaring due largely to the many rural residents migrating to urban areas. The majority of these new migrants are poor and often settle on the outskirts of the urban areas, sometimes in shantytowns.

This widespread phenomenon stresses the urban transportation network in a number of ways. The most important may be that it widens the income gap between wealthier and poorer city residents. The following paraphrased account illustrates how this phenomenon can affect the transportation system in a city over time.¹⁷

Consider an expanding city in a developing country. Migrants from rural areas arrive in the city and settle on the outskirts of town where housing is inexpensive, but where they also will be relying on public transit to get to their new jobs. These migrants are poor and can afford only the lowest level of public transportation — perhaps a bus with low fares wholly owned by a public corporation. The combination of the transit company being publicly owned and therefore not needing to be profitable, and the feeling that raising the prices for public transit would represent a real social injustice, combine to create a “real lack of willingness and capacity to improve service levels.”¹⁸ Meanwhile, early migrants to the city are looking for better service. They have more money now and are tired of not knowing when the bus will arrive and, if they are lucky, sitting on a hard seat. Those that have the means will purchase a vehicle (likely an old, highly polluting one) to avoid the daily ordeal of public transit and will add to the traffic congestion. Meanwhile, the public transit company will continue to provide low-level service to new migrants. And the cycle will continue.

Bus transit is an extremely important mode of transportation in developing cities — typically providing well over 50 percent of all motorized trips. Therefore, the pattern identified above could have significant implications for the future of transportation systems in these cities.

B. The Importance of Institutions

Dealing effectively with the challenges of rapid population growth, rapid motorization, and large groups of low-income travelers would be difficult for cities with substantial financial and institutional resources. Many developing cities have limited funds and planning expertise, and inexperienced local institutions to implement plans and enforce policies. For these cities, effective transportation planning, infrastructure development, and

policy implementation is difficult. Tembele et al. remark that the “experience of the last two decades in Sub-Saharan Africa shows that the big problem is not a lack of good ideas about how the urban transport situation can be improved. The real bottleneck is the absence of a capable and dedicated urban government It is not lack of money Expenditures on transport are actually far too high already.”¹⁹

In Delhi, the problem lies in the lack of coordination among the many institutions that are jointly responsible for maintaining the city’s transportation system. The scale of the problem is illustrated by the following small example. The Public Works Department constructed pedestrian tunnels under a number of busy streets in the city but failed to coordinate with the government agencies that jointly determine the location of bus stops. As a result, pedestrians made little use of the tunnels. After the mismatch was identified, the bus stops were eventually moved, but most failures of this type are not so easily resolved.

Buenos Aires, Argentina provides another example of institutional difficulties. With a history of non-coordination between different modes of public transit, the city found it politically impossible to pass a law to form a metropolitan transportation planning organization. Recognizing the seriousness of the problem, the city successfully procured a loan from the International Monetary Fund to build cooperative relationships “bottom-up” between transportation stakeholders through small projects.²⁰

C. Motorization Trends and Their Determinants

Because current motorization levels are low in developing countries, energy use and GHG emissions from the transportation sector are also relatively low compared to other sectors and more affluent countries. But dramatic changes are likely in the near and medium term.

One of the most desirable items to own in the developing countries (and elsewhere) is a motorized personal vehicle. The evidence is overwhelming. Car ownership is increasing everywhere, and in some countries ownership of motorized two-wheelers is also soaring. Personal vehicles are attractive because they provide flexibility and freedom, and usually shorter travel times. They are often status symbols as well, marking their owners as successful. Scooters and motorcycles have the additional benefit of being easy to park and cars offer greater comfort and safety.

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The principal determinant of vehicle ownership is income. As economies grow and incomes rise, more people can and do purchase vehicles. This link makes intuitive sense, and there are many studies that emphasize the relationship between wealth and car ownership levels.²¹ Vehicle purchases are most responsive to expanding income in middle-income countries — those with average annual incomes between about \$5,000 and \$15,000 — and less so in very poor and very rich countries.²² In this middle-income range, the income elasticity of demand for vehicles tends to be well over 1.0. That is, for every 10 percent increase in income, vehicle ownership increases by at least 10 percent.

It is also important to note that the causal relationship may not be as strong in the other direction. That is, buying and using more vehicles does not necessarily lead to economic growth. In places without roadway infrastructure adequate to support smoothly flowing vehicle traffic, vehicles can be a drain on an economy. The World Bank notes that in Bangkok, “congestion-induced delays cost the city an estimated \$4 million a day.”²³

The relationship between car ownership and income is not fixed, however. Cities and countries with similar income levels will often have very different levels of car ownership. Thus, while income is an important factor in increased motorization, the income effect does not necessarily swamp other effects. This observation is of huge significance because most transportation policies and investments will not affect income much. More important, it implies that there are factors other than income that strongly influence the structure of the transportation system and carbon emissions in particular. Thus, while carbon emissions from urban transportation will rise as incomes rise, there are specific policies that could restrain the growth of carbon emissions from this sector without reducing the income of the population. The important lesson is that while more income will likely lead to more cars, there are a variety of circumstances and policies that can influence this relationship.

Box 2

The Two-Wheeler Mystery

Cities throughout Asia are inundated by bicycles, scooters, mopeds, and motorcycles. Delhi, India, with an average income of about \$800 per capita, has 120 motorbikes per thousand people. Shanghai, with per capita income of \$4,000, has 60 motorbikes and 500 bicycles per thousand people.²⁴ In contrast, two-wheelers (both motorized and non-motorized) are virtually absent in Latin America and Africa. For instance, Santiago, Chile and South Africa, with incomes similar to Shanghai and far greater than in Delhi, have only a scattering of two wheelers. Why is this?

There are various explanations for this mystery. One appears to be economic protectionism, especially in Africa. Countries erect trade barriers to protect small, local (high-cost) manufacturers of two-wheelers. Senegal, for instance, applies high tariffs to protect a domestic manufacturer that sells only 2,000 bicycles per year.²⁵ In contrast, domestic manufacturers in Asian countries have benefited from large populations and therefore large domestic markets, along with low labor costs. With large markets and scale economies, domestic manufacturers in those countries are able to sell bicycles and motorbikes at low prices. New entrants to the market find it hard to compete.

A second factor is topography and security. Many cities in Latin America are located on hilly sites, discouraging the use of low-cost, one-speed bicycles. In Africa, roads are often poorly maintained and unsafe. Recently, DHL and UPS began using human-powered quadricycles and tricycles for deliveries in London and Stuttgart, yet resisted doing the same in African cities. A public relations officer of UPS said, "Riding a bicycle is a dangerous activity in the African countries ... and UPS's policy is to ensure a safe workplace for each of its employees."²⁶

Social and cultural factors also play a role. For reasons not fully understood, two-wheelers are shunned by most urbanites in Africa and Latin America. Still another factor may be the difficulty of purchasing insurance for motorcycles in many countries.

In the end, though, no explanation seems fully satisfactory. Trade barriers have been receding, not all cities in Africa and Latin America are hilly, and most of these cities are less dense than Asian cities, making them more attractive to bicycles and motorbikes. Indeed, Honda recently mounted a large marketing initiative in Brazil and sales of small motorcycles (mostly 125 cc engine capacity) are now soaring. The implications are significant, and highly controversial.

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D. Determinants of Variation Between Countries

Vehicle use varies widely across the globe, and particularly among developing countries. Although the trend within any particular country or city is toward more cars as incomes rise, the starting points are different and the rate of motorization is not universal. Conventional trucks, buses, and cars account for only 5 percent of vehicles in some Asian cities, and as much as 60 percent in others.²⁷ Moreover, the vehicle mix and travel patterns are usually very different from those in more developed countries. For instance, roughly 60-70 percent of Delhi's and Shanghai's motorized vehicles are two- and three-wheelers, and in South Africa, minibus jitney²⁸ transportation accounts for about 33 percent of all passenger-kilometers of travel.²⁹ In contrast, jitney transportation and motorized two-wheelers play a negligible role in most cities of Europe, Japan, and the United States.

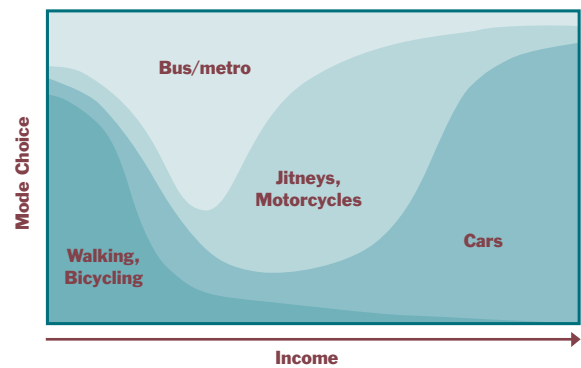
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Despite the diversity of vehicle mix, vehicle use, and travel patterns, there are some common patterns and relationships. Figure 2 illustrates the relationship between income and choice of transportation mode. At a low level of income, people generally take public transit or use some form of non-motorized transport. At a middle-income level, a group emerges that spends a substantial percentage of their travel time in jitneys or (in South and East Asia) on scooters or motorcycles. At a high level of income, a large percentage of trips are made in private cars.

The horizontal scale in Figure 2 is purposefully inexact. The income levels at which travelers move from one mode to another varies greatly from one city to another. For instance, even in developed countries, many cities have not reached the car use indicated on the right side of Figure 2. They may never reach this level, if the alternatives to private cars remain attractive.

Figure 2

Mode Choice and Income



In summary, motorization is clearly linked to income, but many other factors also influence motorization. Public policy and investments could be instrumental in restraining the use of vehicles that are high energy consumers and greenhouse gas emitters.

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III. Policies and Strategies

Transportation-related GHG emissions are growing faster than emissions from all other sectors.

GHG emissions are far more difficult to control than conventional air pollutant emissions, especially in the transportation sector. One reason is that GHG emissions are the end result of a long chain of decisions and desires. GHG emissions are related to energy use, which is related to desire for travel, which in turn is related to a variety of social and economic desires. A second reason is that transportation decisions are made by a wide variety of people and organizations with diverse concerns. And third, strategies to slow the growth of GHG emissions in the transportation sector are not as amenable to technical solutions as they are in other sectors (and as with conventional air pollutants such as hydrocarbons and carbon monoxide, which are readily reduced using “after-treatment” devices).

There are essentially three ways for developing countries to slow the growth in GHG emissions: (1) restrain vehicle demand and use; (2) employ new technology now available in developed countries; and (3) employ “leapfrog” technology. These are discussed below.

A. Restraining Vehicle Demand and Use

Slowing the growth of GHG emissions from transportation by restraining the demand for and use of conventional private vehicles can have broad impacts on lifestyle and behavior. As a general rule, the more people affected and the more behavioral change required, the more difficult any kind of change will be. Given the strong inherent demand for personal vehicles, demand-restraining strategies could require behavioral changes by most individuals. However, this need not imply sacrificing comfort or quality.

These behavioral changes can be modest, and can even result in economically beneficial choices. For instance, most trips do not require conventional private cars. Personal vehicles provide many benefits but they are costly to individuals and to society. The problem is that once individuals own a vehicle, they tend to use them for most trips. That is because most of the costs of vehicle ownership are fixed, paid

upfront, and do not vary significantly with vehicle use.³⁰ This gives owners a strong incentive to use their vehicles for as many of their transportation needs as possible. Since private vehicles are usually the most GHG-intensive transportation mode per passenger-kilometer, private vehicle ownership and transportation GHG emissions tend to rise together.

Once people own vehicles, public transportation use drops, and public transportation tends to lose money as well as political support. Often, the government responds by consolidating routes and reducing the frequency of service to save money, which inconveniences those who continue to rely on public transit. More of these people buy private vehicles and the cycle continues, leading to increasing traffic congestion, high emission levels, rising transportation energy use, and the need for costly, large-scale roadway infrastructure development.

For these reasons, motorization levels largely predict carbon emissions from the transportation sector. Using only the nine cities and countries in Table 2, vehicle ownership statistically explains 90 percent of the difference in carbon emissions per capita. This high level of correlation suggests that a key part of any strategy to induce slower growth in carbon emissions from transportation should be to slow growth in personal vehicle ownership and use. This need not mean sacrificing access to high quality transportation. Restraining vehicle use would give cities in developing countries more time to build their transportation infrastructure to support other kinds of motorization — including buses and rail. This strategy helps reduce traffic congestion, air pollution, and GHG emissions.

Table 2

CO₂ Emissions and Vehicles Per Capita for Selected Countries (1998)

Country	CO ₂ Emissions Per Capita from Transportation (kg)	Percentage of Total Carbon Emissions from Transportation	Cars Per Thousand Inhabitants (1996)**
Chile	1028	28	110
China	178	8	8
India	120	13	7
Mexico	1010	27	143
South Africa	1740*	20*	121
France	2257	35	526
Japan	1971	22	552
United Kingdom	2238	24	441
United States	6082	30	769

Sources: International Energy Agency, 2000. *CO₂ Emissions From Fuel Combustion: 1971-1998*. Metschies, Gerhard P. 1999. *Fuel Prices and Taxation*. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. May. Available on the Internet at www.worldbank.org/html/fpd/transport/urbtrans/other/fuel.pdf.

* These data on South Africa CO₂ emissions were adjusted upward by the authors to account for large amounts of upstream emissions resulting from use of coal-based transportation fuels.

** These car ownership numbers include light duty trucks (important in the United States), minicars and mini-trucks (under 660 cc) in Japan, and exclude motorbikes (important in India and China).

B. Technology Strategies

A second broad set of strategies to reduce GHG emissions is technology based. Technology strategies tend to require less behavioral and lifestyle change, and are therefore easier to implement than policies that restrain vehicle demand and use. In practice, though, the two strategies are usually complementary. The technology strategy focuses on fuels, propulsion technology, other vehicle attributes (such as size), and use of communication and information technologies.

Table 3 presents estimates of GHG emissions for travel modes and technologies. They are based on typical vehicles likely to be operating through 2020 in developing countries. They roughly reflect circumstances likely to prevail over that time period — that is, small increases in energy prices, and gradual adoption of existing and state-of-the-art efficiency innovations. If fuel prices were to be substantially higher than at present or aggressive efforts were pursued to reduce fuel consumption or GHG emissions, these emissions would be lower. The GHG emission factors are CO₂-equivalent measures. They include the principal greenhouse gases and emissions from the full fuel cycle (from “well to wheels”).³¹ The numbers in Table 3 should be treated as illustrative of relative relationships. Much more research and much better country-specific data are needed on this topic.

Table 3

GHG Emissions from Vehicles and Transportation Modes

in Developing Countries

	Load Factor (average occupancy)	CO₂-Equivalent Emissions Per Passenger-Km (full energy cycle)
Car (gasoline)	2.5	130-170
Car (diesel)	2.5	85-120
Car (natural gas)	2.5	100-135
Car (electric)*	2.0	30-100
Scooter (two-stroke)	1.5	60-90
Scooter (four-stroke)	1.5	40-60
Minibus (gasoline)	12.0	50-70
Minibus (diesel)	12.0	40-60
Bus (diesel)	40.0	20-30
Bus (natural gas)	40.0	25-35
Bus (hydrogen fuel cell)**	40.0	15-25
Rail Transit***	75 percent full	20-50

Note: All numbers in this table are estimates and approximations, and are best treated as illustrative. See case study reports in this transportation series from the Pew Center on Global Climate Change for details and differences across cities and countries.

* Ranges are due largely to varying mixes of carbon and non-carbon energy sources (ranging from about 20-80 percent coal), and also the assumption that the battery electric vehicle will tend to be somewhat smaller than conventional cars.

** Hydrogen is assumed to be made from natural gas.

*** Assumes heavy urban rail technology (“Metro”) powered by electricity generated from a mix of coal, natural gas, and hydropower, with high passenger use (75 percent of seats filled on average).

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Even so, Table 3 suggests some fundamental relationships and findings:

- Collective modes of transportation consume far less energy and generate fewer GHG emissions than personal vehicles.
- Vehicles powered by electricity and fuel cells tend to generate considerably fewer GHG emissions than those powered by internal combustion engines.
- Small scooters and motorcycles have relatively low GHG emissions, roughly comparable on a passenger-kilometer basis to rail transit and jitney-type transit services.
- Gasoline tends to have the highest GHG emissions of commonly used fuels. Natural gas tends to rank somewhat better, diesel even better, and electricity best of all (except when coal is used for electricity generation).

Certain of these findings are more precise than others. For instance, diesel-associated GHG emissions are typically about 30 to 40 percent lower than those associated with gasoline because diesel engines are more efficient and diesel fuel contains 11 percent more energy per liter.³² Natural gas used in place of gasoline is likely to generate about 20 percent fewer GHG emissions.³³

Other factors introduce even more variation. Although most vehicle technologies are international, there are vast differences in how they are used, their occupancy characteristics, and in some cases how they are designed. In South Africa, minivans are used for public transportation, even though they were not necessarily designed with this purpose in mind and are typically overloaded. Cars in South Africa also tend to be considerably larger (and less fuel efficient) than those in China and India. In India, the average occupancy of a two-wheeler is substantially greater than one person. Buses in India and China are designed with smaller engines and consume less energy than buses in South Africa (and in most industrialized countries). In summary, the numbers in Table 3 are subject to many qualifications and can vary considerably.

In exploring technology-based strategies and options to restrain GHG emissions, consider that three waves of technological innovations are sweeping through the international automotive industry. While these innovations generally take hold later in developing countries than in more affluent industrialized countries, they will eventually be adopted, sometimes quickly.

The first two waves of technological innovations are pervasive and already have generated large benefits. The first is aimed at reducing air pollutant emissions from conventional internal combustion

engines. These changes are underway in most developing countries in response to the adoption of more stringent emission standards and greater foreign investment in local automotive industries. These changes include improvements in combustion processes, treatment of exhaust gases (e.g., with catalytic converters), and use of cleaner burning fuels. However, exhaust gas treatment for pollution reduction will have little effect on energy efficiency or GHG emissions. The use of natural gas, alcohol fuels, and propane in gasoline engines will provide reductions of about 20 to 30 percent in GHG emissions, but their use in diesel engines will not reduce GHG emissions and may even slightly increase them.

A second wave of innovation is aimed at increasing the energy efficiency of conventional engines. Vehicles manufactured in India, China, and other developing countries generally do not incorporate international state-of-the-art efficiency technologies. If the Indian and Chinese auto industries were to adopt technology already available in the international market, fuel consumption would be substantially reduced. The average fuel economy for new, small cars sold today in India is over 30 miles per gallon (mpg) (8 liters/100 kilometers). Small two-stroke motorcycles achieve over 80 mpg (3 liters/100 km) and buses over 7 mpg (34 liters/100 km). These impressive fuel economy numbers are not the result of state-of-the-art technology, but low power and small size. With more advanced technology, considerable improvements are possible. Automakers are continuing to increase vehicle efficiency in response to tightening fuel economy standards in Japan, voluntary CO₂ standards in Europe, and high fuel prices in most countries. In the United States, vehicle energy efficiency is also being improved, but the improvements are diverted to increase vehicle power and size, and to add energy-consuming features such as four-wheel drive.

A third wave of innovations is more radical. It involves a transition away from internal combustion engines to electric-drive propulsion technology. These innovations have the potential for the greatest reductions in GHG emissions. The use of electric-drive systems — fuel cells, batteries, and hybrid electric systems — would improve energy efficiencies by 50 percent or more with the potential for much less pollution. These technologies are still novel and expensive, but costs are dropping quickly and could be cost-competitive with conventional technologies within one to two decades. Small numbers of battery-powered scooters and cars are being sold in India, Taiwan, and elsewhere. Competitively priced hybrid electric vehicles became available internationally from Honda and Toyota in 2000, and several other automakers have announced plans for mass production of hybrid vehicles by 2004. Fuel cell buses will be

provided to Shanghai, Delhi, and number of other cities in developing countries and in Europe in 2002-2003, though at high prices and with large subsidies.

Another set of innovations is designated as “intelligent transportation system” (ITS) technologies. These are information and communication technologies that can be used to control roadway congestion and improve the efficiency and service of public transit. These technology strategies include ramp metering³⁴ on highways and information dissemination about roadway congestion, accidents, and real-time arrivals of buses and trains. They can also aid in creating “smart” carsharing services (described later) and electronic toll collection, and other services that might be suited to suburban development patterns.

All these propulsion, fuel, and ITS technologies can be used in developing country settings, and most already are to a limited extent. However, appropriate application is crucial to their success. Technologies that work in developed countries may not work in developing countries due to their expense, maintenance needs, fuel availability, or need for high levels of institutional support.

C. Leapfrog Technologies³⁵

Why not expedite the use of fuel cells, smart transit services, and other cutting-edge technologies? Why invest in dated technology? Why not skip over the relatively dirty and inefficient internal combustion engine, the large fuel production and distribution infrastructure associated with petroleum, and the chaos of “unintelligent” roads and transit systems? In the telecommunications industry, cellular phones are replacing wires as the physical equipment needed for communication all over the world. In developing countries, this technology is making it easier than ever for people to connect to each other and to the rest of the world, “leapfrogging” past the need for telephone lines. Leapfrogging has considerable merit.

As indicated above, advanced transportation technologies are already being pursued in developing nations. Electric bicycles and scooters are being used in Shanghai and a number of other cities to reduce urban air pollution. Some cities are switching buses, taxis, and other vehicles to natural gas. Still others are about to experiment with fuel cells. ITS technology is used to control roadway congestion and collect tolls in many developing country cities.

Unfortunately, the leapfrog approach is far less compelling in transportation than it has been with cellular phones. Transportation technology does not harbor any perfect solutions that will revolutionize the way people and goods get around. Some fuel, propulsion, and ITS options are currently available and their deployment could be accelerated, generating sizable emissions or energy savings. But generally speaking, they tend to be far more costly than conventional petroleum combustion technologies and, in the case of ITS technologies, require huge financial and institutional investments. Even in Shanghai, one of the best-managed cities in the world, there were substantial problems and large expenses associated with the deployment of ITS technologies to manage roadways. Advanced transportation technologies are clearly an attractive option in developing countries, but great care must be given to adapt to the setting, anticipate unexpected costs, and provide the expertise and institutional investments to implement these technologies successfully.

The only leapfrog technology that provides the potential for large improvements may be fuel cells. Fuel cell vehicles are more energy efficient and less polluting than today's vehicles, and potentially cost competitive. But the fuel cell case highlights the leapfrog challenge. First, they are far from cost competitive at present. Any country seriously contemplating a leap to fuel cells would need to invest many tens of billions of dollars in its domestic automotive industry, or patiently await investments from foreign companies. Fuel cells are not implausible as a means of partially leapfrogging petroleum and internal combustion engines, but fuel cell vehicles are not expected to be mass marketed before 2010 in affluent industrialized countries, and thus such a leap could not begin in developing countries for at least 15 years.

Consider the case of China, the most likely candidate for this fuel cell strategy. Shell International, well known for its prescient scenario planning group, recently developed two energy scenarios. In the more ambitious scenario, Shell posited that by 2025, China, with one-fifth of the world's population, limited petroleum reserves, growing vehicle use, and a rapidly expanding economy, would be facing untenable levels of oil imports. The following Shell scenario description, paraphrased below, suggests the complex set of circumstances and tortuous path by which China might pursue fuel cell vehicles.³⁶

China would push towards the use of indigenous coal. But doing so would become logistically and environmentally problematic. Meanwhile, growing global demand for [natural] gas and hydrogen would be supported by — and spur — advances in low cost and unobtrusive in-situ extraction of methane and hydrogen from coal. Carbon dioxide sequestration would become feasible and enhance productivity in this

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scenario. China is able to make use of these, as well as indigenous technologies, to extract methane and hydrogen directly from its coal resources, allowing it to move energy by pipeline rather than thousands of trains. According to the Shell scenario, once fuel cells take off in OECD countries, China starts to develop a transport and power system around cost-effective fuel cells fueled by indigenous methane and hydrogen.

Other types of initiatives, not based on technology, are potentially more significant. The authors conclude, based on the four case studies prepared as part of this series of reports on transportation in developing countries, that initiatives based on institutional reform are more likely to revolutionize transportation. An enhanced level of coordination between transportation agencies and governments with land use control could lead to dramatic improvements in transportation efficiency and reductions in vehicle usage in ways that have rarely been seen in the past.

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+ **Transportation** In Developing Countries

IV. Policy Options

Greenhouse gas emissions are not a major driver for policymaking in the transportation sector anywhere in the world, although the contribution of transportation to global warming is significant. The global transportation sector was estimated to be responsible for 22.7 percent of worldwide carbon dioxide emissions in 1997, and emissions from this sector are growing faster than any other.³⁷ Yet it is difficult for local policymakers facing more immediate problems to address a long-term global problem like climate change.

Fortunately, there are many policies and investments that meet local transportation needs and also result in lower GHG emissions. These options are examined and sorted below. However, there is no optimal prescription for any one region, and certainly no uniform prescription that can be broadly applied.

One way to understand the complexity of choices is to conceptualize the problem of GHG emissions as a “tragedy of the commons” — a conflict between private and public interests — and to examine responses by different societies. The U.S. response tends toward accommodation of private desires. This approach reflects the country’s plentiful open space and financial resources, and a national philosophy of independence and individualism. One manifestation of this response is the large number of minivans, pickup trucks, and sport utility vehicles for personal use.³⁸

Most countries in the Americas have philosophies of independence and individualism similar to that of the United States, but do not have the financial resources to reach the same level of personal vehicle ownership and use. In contrast are societies with high population densities, limited financial resources, group-oriented cultures, and strong governance. In these societies, policies and investments that favor societal rather than personal choices may be more acceptable. Effective policies respect these societal differences.

A. A Policy Framework

There are five fundamental strategies to reduce GHG emissions from the transportation sector:³⁹

1. Increase vehicle efficiency
2. Switch to less greenhouse gas-intensive fuels
3. Switch to less greenhouse gas-intensive transportation modes
4. Decrease travel distance
5. Increase occupancy of vehicles

Each strategy can be pursued using a variety of policies and investments (see Table 4), which fall into three general categories:

- Direct mandates through regulation
- Market-based policy instruments, such as taxes, subsidies, or roadway tolls
- Direct investment

Table 4:

Illustrative Strategies and Policies to Reduce Pollution and GHG Emissions

	Regulation	Market-based Instruments	Direct Investment
Vehicle Efficiency	Performance standards such as the U.S. CAFE ⁴⁰ standards	“Feebate system,” ⁴¹ fuel tax, accelerated vehicle scrappage program, “gas-guzzler” tax	Investment in R&D to improve vehicle design for efficiency
Fuel Choice	Mandates such as the decision requiring all Delhi buses to run on compressed natural gas	Subsidies for alternative fuel vehicles; fuel tax differentials for alternative fuels	Investment in R&D and marketing of alternative fuel vehicles
Mode Choice	Bans on private vehicle use in city centers	Subsidies for transit riders; roadway tolls and parking fees in areas that are accessible by transit	Investments to increase and improve the quality of transit service, such as carsharing and other private car alternatives
Travel Activity	Mixed-use zoning, no-drive days	Market incentives for high density development	Investments in optimizing logistics for goods delivery
Vehicle Occupancy	Laws prescribing the number of passengers per vehicle entering city centers	Incentives for carpooling such as HOV lanes ⁴²	Investment in intermodal freight transportation centers; investment in more comfortable public transit vehicles

B. Synergistic Policies and Investments

*Sometimes, if more than one strategy is implemented, the resulting effect on GHG emissions is greater than the sum of the effects due to the separate actions.*⁴³

Imagine a region that aims to slow the growth of GHG emissions by encouraging a shift from private cars to public transit. The region considers the policy of raising the cost of driving by increasing tolls on heavily travelled routes and investing in enhanced public transit service. If the region implements only the policy or just makes the investment, the resulting mode shift is likely to be relatively small. However, if the region is able to coordinate the two strategies, the resulting behavioral change may be substantial.

Consider the following three success stories.

Singapore

Singapore is a small, affluent country with low car ownership and extensive, high quality transit service. The low motorization rate did not evolve effortlessly. In the 1950s, Singapore had a high motorization rate for its income. Its leaders explicitly set out to reverse that relationship — with success.⁴⁴ Singapore restrained vehicle ownership *and* use, invested aggressively in public transit, and controlled land use development. +

Investment in bus and rail transit in Singapore has been substantial. The rail transit network was carefully designed in coordination with land use development plans. Stations are located near 40 percent of all businesses and within walking distance of 30 percent of all Singaporean residents.⁴⁵ The government also strongly discouraged car ownership and use. A very high “additional registration fee” (ARF) was imposed on vehicle purchases until 1990, which was then replaced by an auction system. At its height, the ARF reached 150 percent of the vehicle’s market value; the bid price for the right to purchase a vehicle under the current system is similarly high. In parallel, vehicle usage has been restrained with high road tolls and parking fees. +

Until 1998, drivers entering certain areas of the city were required to purchase an expensive license; this requirement was later replaced by electronic road pricing. Some argue that the total cost of driving in Singapore is greater than the full private and social cost of owning and operating vehicles, and that the government has been too aggressive. Whether or not this is true, Singapore has emerged from poverty in the 1950s to

be one of the most affluent countries in the world (on a per capita basis), with among the highest quality of life ratings⁴⁶ — and with very low transportation energy use and GHG emissions for a country of its income.

Shanghai, China

Shanghai is similar in many ways to Singapore, but at an earlier stage of development and on a much larger scale (16 million people in Shanghai versus 4 million in Singapore). Shanghai has a sophisticated planning organization that coordinates transportation decisions with other land use and city planning policies. The municipal government has considerable control over land use and can coordinate housing and transit investments in a way that is impossible in many other parts of the world. Shanghai is executing an ambitious plan to decentralize the extremely crowded city and build satellite cities with coordinated investments in rail transit and major highways. It has also adopted strong disincentives for car ownership, including high taxes on vehicles and registration caps. The result to date is impressive.

Curitiba, Brazil

The city of Curitiba, Brazil, is a superb example of policy coordination, in this case between land use planning and public transit investments. Curitiba is among the few cities in the world that has implemented a linear pattern of development together with an efficient transportation system. Buses efficiently serve the entire city with a hierarchy of routes, including feeder routes and a limited number of dedicated routes

Box 3

Carsharing

Carsharing provides travelers with access to personal vehicles when they most desire them, thereby reducing demand for individual car ownership. Individuals belong to a for-profit or non-profit organization that owns vehicles. The vehicles are dispersed at parking lots where carsharing organization members live and work. These might be situated every few blocks in a city, at apartment buildings, and at key destination sites, although there are many ways to organize such services. The benefit to the user is access to a range of vehicles for different needs and carrying capacities, without having to bear the cost and responsibility of vehicle ownership. The practice is gaining popularity in Europe. The European Carsharing

(ECS) network, founded in 1980, operated in 350 cities in Germany, Austria, Switzerland, and the Netherlands in 2001, and is expanding. The potential may be even greater in developing countries where vehicles are far more expensive relative to income.

The benefits to society are potentially large. Many members forego buying a car and travel less since they pay per use. For those who don't own cars, they now benefit from the positive attributes of cars without having to pay for one. Carsharing in Singapore is beginning to take hold, and many other cities around the world are examining this option with pilot projects and research.⁴⁷

for double-articulated buses.⁴⁸ Development was strongly encouraged along the dedicated routes. At the same time, much of the city center was converted to pedestrian-only streets that are most easily accessed by public transit.⁴⁹

C. The Importance of Local Circumstances

Because local circumstances – political, economic, geographic, environmental, social, and institutional – vary significantly, policies and strategies are not easily replicated. Consider two of the examples above. Singapore does not have the geography or topography to develop as a linear city, but it does have a population willing to limit its personal desires for the greater public interest, and a strong and resource-rich central government able to craft effective policies. Curitiba, on the other hand, did not have the local institutions and culture that readily lent itself to strong control of vehicle ownership but crafted other strategies that worked well in that setting.

In different parts of the world, successful strategies to slow the growth of GHG emissions in the transportation sector will be different due to the variety of existing transportation systems and political environments. There are, however, some identifiable factors that are likely to influence the outcome for most societies. Factors that affect which strategies are likely to be successful include the following:

- Degree of centralization of authority
- Policy and investment precedents
- Existing land use patterns, and topographical and geographical constraints
- Group-oriented cultural norms in the society
- Strong policy enforcement capabilities of local institutions
- Local commitment to related policy goals such as air quality improvement
- Economic and political influence of local interest groups such as automotive and oil suppliers
- Strength of local public interest non-governmental organizations

The interplay of these factors in each city and country leads to very different outcomes. For instance, in many countries and cities, a business tradition has evolved of company cars — vehicles financed, owned, or subsidized by employers and provided to employees for business and personal use. In Shenzhen, China, in the mid-1990s, 70 percent of vehicles reportedly were company cars.⁵⁰ Even in places such as the United Kingdom, this ratio can be very high, reportedly approaching 50 percent of

sales in the early 1990s, though the number has receded there as laws and loopholes were tightened. The presence of company cars, aided by local tax structures, undermines fiscal strategies supporting public transit and restraining car ownership and use. This practice inflates vehicle sales and results in relatively large vehicles, since users are not absorbing the cost of the vehicle.

In Chile, in another example of a unique interplay of factors, truckers initially opposed paying tolls on the privatized intercity highways, on the grounds that the tolls would be too costly. The conflict was resolved in April 2000, when they were offered a 50-percent reduction in diesel fuel taxes.⁵¹ In South Africa, decades of Apartheid policies transformed much of the land use, transportation, and energy systems of the country. Black residential areas were moved far from city centers, requiring expanded transit services with large subsidies to serve this work force. Black-owned jitney services were allowed to flourish to ease the government's subsidy burden. High-carbon, domestically produced synthetic fuels were subsidized to counter international sanctions. An effective policy agenda must acknowledge these local circumstances.

There are also many examples highlighting energy and transportation options that might be mutually beneficial. In Jakarta, Indonesia in 1991, traffic congestion increased fuel consumption an estimated 30 percent.⁵² Improved traffic management would provide a double benefit: increased traffic flow and reduced energy consumption. Likewise, in Bogotá, Colombia it was found that fuel consumption was 25 percent higher for a vehicle moving on a gravel or earth surface than on an asphalt pavement.⁵³ By improving road maintenance and upgrading road surfaces, Bogotá could also reduce both traffic congestion and fuel consumption, providing mutually reinforcing benefits.

D. Transportation Financing

Many megacities of the developing world are still expanding, and several are approaching income ranges where vehicles become affordable for large segments of the population. In many of these already large cities, relatively little space is devoted to roads — less than 10 percent in many Chinese cities versus 15 percent in pre-auto Manhattan.⁵⁴ The dearth of roads — and haphazard development patterns — increases the challenge of accommodating growing vehicle usage.

“Most [developing country] cities have developed and expanded with such a spatial incoherence that it is very difficult to organize cost-effective public transport. In the absence of land-use planning, and where illegal settlements become the only viable source of housing for most low-income groups, cities expand in a haphazard manner, with very densely populated settlements of different sizes interspersed with large areas with little or no development and often low density suburban developments for middle and upper income groups. This greatly increases the cost of providing public transport.”⁵⁵

The timeline for transportation system development in today’s developing countries is compressed compared to that of already-affluent cities and nations. The rapid speed of development creates pressure for substantial investments within a relatively short time period. Finding the resources to finance the needed infrastructure investments is a challenge in many parts of the developing world.

Multilateral lending institutions have had an important influence on the development of the transportation sectors in many countries since they are the major lenders to governments for large public infrastructure projects. This historical role as financiers of major infrastructure has more recently been challenged by the emergence of private sector finance sources.⁵⁶ An additional non-conventional source of financing that is emerging is the Clean Development Mechanism (CDM) (see Box 4), part of the 1997 Kyoto Protocol to the United Nations Framework Convention on Climate Change.⁵⁷ The private sector is



Box 4

The Clean Development Mechanism

The Clean Development Mechanism (CDM) is one of the market-based flexibility mechanisms of the Kyoto Protocol. The CDM encourages investment in greenhouse gas reduction projects in developing countries by allowing industrialized countries to apply some of the emission reductions from projects they undertake in developing countries toward their Protocol targets.

Many policies and investments to slow the growth of transportation-related GHG emissions are desirable for economic and local environmental reasons. However, many developing nations have such scarce financial resources that they cannot pursue even the most attractive of these options. The CDM, whose details are currently being defined, is a potential funding source.

The CDM allows an industrialized nation to invest in a project in a developing nation to reduce GHG emissions “that are additional to any that would occur in the absence of the project activity.”⁵⁸ The investor and host nations would then receive GHG emissions reduction credits to allocate amongst themselves. These credits can be sold or applied toward meeting the industrialized country’s Kyoto Protocol emission reduction obligations. Alternatively, a developing nation could undertake a project on its own, without the participation of a developed country, and sell the resulting credits in the international GHG emissions market. One prospective example might be investments in South Africa’s synfuel industry, to convert the feedstock from carbon-intensive coal to cleaner and less carbon-intensive natural gas.⁵⁹



Perhaps the most important new source of transportation financing is related to privatization of public facilities and services. Many parts of the developing world, particularly in Latin America, are selling roads, ports, railroads, and other facilities, or sometimes just the operating rights, to private companies as a means of financing the operation and expansion of those facilities. While privatization is an attractive solution to the funding woes of developing country governments, the process of privatization creates a new mix of winners and losers that merits close scrutiny.

Chile has pursued privatization of inter-urban transportation facilities and services perhaps more aggressively than any other nation in the world. In 1990, in response to long periods of deferred investment, the government launched an ambitious franchising program for both roadways and freight railways. Today, all of the main highways in Chile are built, financed, and operated by private companies. In the future, smaller roadways and even urban streets may be privatized as well. Freight railways and the right to use tracks have been sold to private operators, resulting in greatly increased business on many lines.

Financing of urban infrastructure and services has been a problem in many developing cities, leading to interest in privatization. The bus system in Shanghai is a prime success story. In the late 1980s, the bus system owned and operated by the local government was notorious for offering poor service and requiring very large subsidies. The bus system was converted from an entirely state-owned enterprise to a number of separate bus companies. The transition was gradual, with each bus company receiving a decreasing amount of government funding for several years. Eventually, each one was forced to become financially self-sufficient.⁶⁰ The result is an efficient and financially viable bus system.

Not every bus privatization story is as successful, however. When Santiago, Chile fully deregulated its bus system between 1975 and 1988, the network expanded and waiting time at bus stops dropped. However, fares doubled; older, more polluting, and more dangerous vehicles were used; and traffic congestion worsened as many small buses replaced larger ones. In 1990, when regulation of bus routes returned with a more restrained privatization scheme, most of the problems were mitigated.⁶¹

Financing urban transit services is a problem for most governments. More affluent passengers choose personal vehicles, leaving transit services with declining revenue and a poorer clientele. As indicated earlier, this starts a downward spiral, in which transit operators downgrade the quality of service and

fewer people choose public transportation. This downward spiral has provided opportunities for private companies and innovative services. Among other responses, private bus companies and van services step in to provide superior service for select market segments. Extreme examples are Karachi, Pakistan, where the public bus operator carries only 18 percent of all public transportation trips,⁶² and South Africa, where private jitneys carry two-thirds of all transit passengers.⁶³

Most observers agree that privatization of transportation services and infrastructure should be done carefully, with government oversight of routes, fares, and tolls. The main lesson from international experience with bus system privatization is that the benefits “depend critically on whether effective competition can be established and maintained in the industry.”⁶⁴

E. Institutional Capabilities

The policies and investment strategies discussed in this section are not novel. All have been implemented in various combinations in cities all over the world. It is rare, however, for them to be implemented based on a coordinated transportation and land use plan and with strong institutional support. Still, cities of today are able to learn from others’ policy successes and failures, allowing them to choose the policies that make the most sense for their situation.

What is different for developing country cities of today is that their economies and populations are growing at much faster rates than was the case for cities in the now-developed world. Therefore, it is crucial that transportation and land use planning institutions in developing cities coordinate their efforts to reach common goals. Perhaps the most important strategy and highest priority in responding to transportation and environmental challenges is to strengthen local institutions, particularly in urban areas. The speed with which many of these developing country cities are moving toward development is unprecedented; strong, coordinated planning institutions are all the more necessary to guide them.

The challenge is great. In Delhi, India, for example, the “local government” responsible for transportation planning actually consists of as many as a dozen separate agencies that historically have not coordinated well. In response to a lawsuit by a nongovernmental organization on the premise of protecting the health of the people of Delhi, the Supreme Court of India launched a variety of controversial initiatives, including a requirement that all buses and taxis convert to natural gas. The directives were not the result of a careful assessment of options, and focused on technical fixes rather than more fundamental

shifts in land use and behavior. These policies reflected a mood of desperation about air pollution and exasperation with the existing metropolitan institutions.

A U.S. National Academy of Sciences report highlights the issue of insufficient institutional capacity:

“[D]eveloping countries face a number of institutional problems that are less prevalent in the industrialized nations, including the absence of reliable bases for funding of public-sector activities, fragmentation and overlap of institutions in the metropolitan areas, inadequate or poorly trained technical staff for planning and implementation functions, and the inability to enforce complex regulations and laws.”⁶⁵

This problem is especially difficult because the transportation system is so complex. The system serves a large number of different constituencies, each with its own interests, including strong industrial groups such as automakers and construction companies. At the same time, it must fulfill important public service roles such as providing mobility to the poor and physically handicapped. It must closely coordinate with land use, environmental, and energy policies, and continually respond to the tension between the public good and private desires. Achieving all this with limited resources in a period of rapid growth is indeed a challenge. International efforts need to focus on strengthening the decision-making, analysis, planning, and enforcement capabilities of local institutions in developing countries to help facilitate successful transportation initiatives.

V. Pathway Choices

Transportation-related decisions made now can have enormous GHG emissions implications for years to come. One size and style of transportation plan definitely does not fit all. Governments in different areas choose different mixes of policy instruments to influence the development of their local transportation systems, as discussed earlier.

A. Four Case Studies

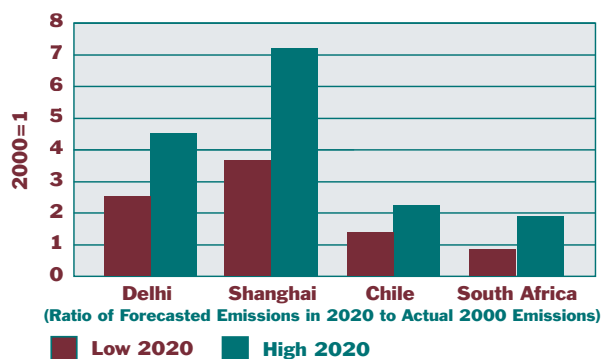
This report builds on four case studies published by the Pew Center on Global Climate Change. Two city case studies, Delhi and Shanghai, and two country case studies, Chile and South Africa,⁶⁶ were part of this series on transportation in developing countries. Each included scenarios of high and low GHG emissions trajectories for the transportation sector in 2020, along with brief stories of how the city or country might arrive at those emissions levels. Figure 3 presents the high and low emissions trajectories for each of the four studies, measured as increases from 2000 to 2020. On the vertical axis, 1 represents emissions in 2000, 2 represents twice the 2000 emissions, and so on. The economic growth rate was equal for both scenarios in each case study region, based on official or consensus forecasts of economic growth, but varied from region to region.

Only South Africa showed a possible reduction, mostly due to anticipated population declines and shifts away from the highly carbon-intensive synthetic fuels that now comprise about 40 percent of the country's transportation fuel mix. Emissions growth will be rapid in Shanghai chiefly because of strong projected economic growth, urban decentralization (resulting in more and longer trips by personal vehicles), and rapid increases in long-suppressed car ownership. Rapid

Figure 3

Transportation Greenhouse Gas Emissions:

Results from Scenario Analyses



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increases in Delhi are mostly due to large population increases. While these emissions increases are large in some instances, differences between high and low scenarios are also substantial, suggesting that policy intervention can have a large effect on the level of transportation-related GHG emissions.

Box 5

Transportation in Developing countries: Four Case Studies from the Pew Center Series

Massive increases in transportation-related GHG emissions are unavoidable in the near to medium term in the developing world. In countries with expanding economies, even the strongest transportation and GHG reduction strategies will be overwhelmed by rapid urbanization and motorization. Nonetheless, there are many opportunities, often at very low cost, to restrain these increases. In the longer term, enhanced technology can be used to reverse these increases.

Delhi: Rapid growth in population and poor transit service are combining to increase vehicle ownership — especially scooters and motorcycles — leading to massive increases in pollution, traffic congestion and GHG emissions. Delhi demonstrates that personal transportation can be achieved at relatively low incomes — but at a high economic, environmental, and social cost. So far, Delhi has largely failed to respond to these transportation-induced crises. Continued failure to do so will further accelerate vehicle ownership and its negative consequences.

Shanghai: Rapid economic growth and planned decentralization of this very densely populated city, and local and national promotion of the auto industry, are likely to lead to rapid increases in motorization, energy use, and GHG emissions. So far, Shanghai has been a model of balanced investments in roads and transit, integrated transportation

and urban land use planning, and effective restraint of vehicle ownership and use. Whether it can continue to manage transportation demand as it expands economically and spatially remains to be seen. If so, it can be a worldwide example.

South Africa: South Africa has very high per capita vehicle ownership and GHG emissions for a country of its income. The direct causes are reliance on carbon-intensive synthetic fuels, long commutes for black workers, protected vehicle manufacturing, and subsidies for “company cars,” all related to the country’s apartheid legacy. With a weak economy, limited public funding, high GHG emissions, and increasing reliance on the private sector, South Africa provides an opportunity to attract foreign investment by hosting a CDM project.

Chile: With a strong economy but a skewed income distribution, vehicle ownership is high, causing severe air pollution in its capital city and high per capita levels of energy use and GHG emissions. As one of the most enthusiastic and sophisticated countries in the world at transferring transportation infrastructure and services to the private sector, Chile has the potential to pioneer market-based approaches to transportation and environmental challenges. The motivation would be local air pollution reduction and access to additional financing.

B. To Follow or Not To Follow the Path of Developed Countries and Cities

Affluent cities that were built after the advent of cars, such as Los Angeles and Houston, are highly car dependent. Older cities that were built earlier, such as New York and Paris, have dense city centers served mostly by walking and transit, but are surrounded by low-density suburbs with high car use. Do developing cities need to find a different transportation development pathway than cities of Europe, North America, and Japan?

Megacities such as Delhi, Bangkok, and Santiago have insufficient institutional capacity, like pre-car cities in Europe and North America. But consider the differences:

- *Many of today's developing megacities are far larger and often far more dense than pre-car New York and Paris.*
- *Today's personal vehicles are less costly than early 20th century vehicles,⁶⁷ and are affordable by increasing numbers of people in the developing world.* The cost differential is especially great because today's travelers have access to low-cost scooters and motorcycles and a used vehicle market. The large used car market is due to the higher quality and longer life of today's vehicles, and the large number of legal and quasi-legal exports of used cars from Japan and elsewhere.
- *The consequences of mistakes (and inaction) are far greater.* Traffic congestion is a mounting problem in almost all cities of the world, but it is more critical in developing country megacities. These cities tend to account for a larger share of their nation's economic activity and the congestion is occurring at lower vehicle ownership levels (raising concerns about what happens as vehicle ownership increases).

The motorization challenge is great in countries with modest economic growth, but especially so in cities with vibrant economies. Developing country cities do have some advantages as they confront motorization. They have access to a worldwide storehouse of knowledge and experiences and superior communication and transportation technologies. As a result, connections are much easier now, electronically and physically, and can be accomplished more cheaply, cleanly, and efficiently than ever before. Emerging cities and nations are highly vulnerable to economic and environmental disasters, but they are in a position to avoid the mistakes and detours taken by many developed countries, and to take shortcuts to a better future.

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VI. Conclusions and Recommendations

Specific policy options aimed at slowing the growth of transportation-related GHG emissions from developing countries vary widely. Some of the principles developing countries might follow in pursuing a more economically, socially, and environmentally superior path include the following:

- Integrate residential and economic activities
- Opportunistically pursue enhanced technologies such as four-stroke motorbikes
- Use market-based policy instruments and private sector suppliers and operators where desirable
- Preserve and enhance the attractiveness of non-motorized transportation options
- Discourage the use of conventional full-sized private cars in cities
- Energetically pursue conventional and unconventional alternatives to current car usage and ownership patterns

As indicated above and throughout this report, there are numerous policy and investment options that are likely to slow the growth of GHG emissions from the transportation sector, many of which might also be attractive for other reasons such as local air quality, economic growth, and public safety. It is vital to the success of any policy, however, that its implementation is feasible within the existing local institutional and cultural context.

It is also important to appreciate that some sets of policies interact in ways that are likely to make the effect of a policy package on GHG emissions greater than the sum of its parts. To the extent possible, synergistic policy and investment packages should be sought and implemented.

In the end, climate change is a global problem that requires a global solution. Developing country transportation systems pose some of the greatest opportunities for making a significant change in the trajectory of transportation sector GHG emissions worldwide. However, local decision makers in these

countries have more immediate problems and limited financial and institutional resources. It is therefore appropriate for industrialized nations to invest in the sustainability of the future of developing country transportation systems, providing both financial and institutional support.

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9. The World Bank, 26.
10. Birk and Reilly-Roe, 99.
11. Lathrop, William. February 1971, "San Francisco Freeway Revolt," *Transportation Engineering Journal of ASCE*, 97, 133-144.
12. Two-wheelers with engine capacity less than 50 cc.
13. The World Bank, 72.
14. A vehicle-mile is defined as one vehicle moving one mile.
15. The World Bank, 69.
16. National Research Council, 4.
17. Viegas, José M. 1998. "Efficiency and quality of public transport in developing cities," *Urban Transport Policy*, Freeman and Jamet (eds.), 177-181.
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21. Sathaye, Jayant, and Michael Walsh. 1992. "Transportation in Developing Nations: Managing the Institutional and Technological Transition to a Low-Emissions Future." *Confronting Climate Change*, Irving M. Mintzer (ed.), New York: Cambridge University Press; Dargay and Gately; Schipper and Marie-Lilliu.

22. GDP elasticity of demand is the percent increase in demand for vehicles that results from a one percent increase in GDP. Dargay and Gately find that the GDP elasticity of demand for vehicles was 0.33 for the United States and 0.65 for Germany, but over 1 for India (1.01), China (1.22), and Mexico (1.71). Wohlgemuth, N. December 1997, "World transport energy demand modelling - Methodology and elasticities," *Energy Policy*, 25:14-15, 1109-1119, found that the GDP elasticity of demand for passenger-kilometers for all passenger modes was estimated to be 0.95 in China and 1.70 in India. Commercial transportation showed similar values.

23. The World Bank, 94.

24. Statistics on motorbikes are of questionable reliability in most cities. Many are not registered for various reasons, especially the smallest (e.g., mopeds). The Shanghai data presented here appear to be accurate — with about two-thirds being under 50 cc — but the Delhi data are less reliable (with the numbers possibly being even larger).

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26. Cited in "News Briefs" of *Sustainable Transport* 12, 4.

27. The World Bank, 75.

28. A minibus jitney is a minivan used for public transit services, also called a combi taxi in South Africa. The vehicles are modified by replacing luggage space with an extra row of seats. Carrying capacity is between nine and 16 people, including the driver. Services are provided with no prescribed timetable, route, or fares.

29. Bose et al. 2001. *Transportation in Developing Countries: Greenhouse Gas Scenarios for Delhi, India*. Pew Center on Global Climate Change. Arlington, Virginia; Zhou et al. 2001. *Transportation in Developing Countries: Greenhouse Gas Scenarios for Shanghai, China*. Pew Center on Global Climate Change. Arlington, Virginia; and Prozzi et al. 2002. *Transportation in Developing Countries: Greenhouse Gas Scenarios for South Africa*. Pew Center on Global Climate Change. Arlington, Virginia.

30. Vehicle purchase price and insurance costs remain more or less constant, while fuel costs and road use charges vary entirely with vehicle use, and vehicle maintenance costs depend partially on usage. Depreciation of a vehicle's value is clearly related to its level of use, but most individuals do not fully take this cost into account in their daily transportation decisions.

31. "Well-to-wheels" refers to all production and distribution activities related to fuels and vehicles, from the oil or gas well or coal mine to the final vehicle user.

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32. Diesel engines may generate a mix of emissions with less warming effect than gasoline engines. Diesel and gasoline engines generate different amounts of NO_x, SO_x, and particulate matter including black carbon (soot). The global warming potential (GWP) of black carbon is highly controversial, even whether it has a net warming or cooling effect. In this report, the authors assumed a positive GWP for black soot (net warming effect).

33. On the other hand, consider that when coal is the source of electricity, electric-powered vehicles tend to rank closer to diesel fuels; when gasoline is made “synthetically” from coal, as in South Africa, it ranks far worse; and when diesel is made from natural gas, it ranks similar to petroleum-based gasoline.

34. Ramp metering is a method for limiting vehicles entering a freeway, bridge or other facility (usually with red and green lights) so as not to overwhelm flows on the facility. Ramp metering, combined with real-time monitoring of traffic flows, increases the throughput of the facility.

35. Leapfrog technologies are technologies that enable users to skip one or more generations of technologies.

36. Shell International, *Energy Needs, Choices and Probabilities: Scenario to 2050*, Global Business Environment, London, 2001, 50-52.

37. International Energy Agency. 2000. *CO₂ Emissions from Fuel Combustion:1971-1998*, Paris: IEA.

38. It is important to note, though, that even in the United States, some public concerns, such as air quality, are highly salient, resulting in extraordinary efforts to protect the local atmospheric “commons.”

39. This breakdown closely follows Schipper, Lee, Céline Marie-Lilliu, and Roger Gorham, June 2000, *Flexing the Link between Transport and Greenhouse Gas Emissions: A Path for the World Bank*, International Energy Agency, Paris.

40. CAFE is “corporate average fuel economy.”

41. A feebate system includes fees and rebates. First, a rate of vehicle GHG emissions (or energy use) per kilometer is chosen. Consumers who purchase a vehicle that exceed this level pay an extra fee, and consumers who purchase vehicles that have lower emissions than this level receive a rebate.

42. HOV is “high occupancy vehicle.”

43. For a more detailed discussion of interaction effects between potential actions to reduce GHG emissions from the transportation sector, see Schipper et al., 2000.

44. Willoughby, C. 2001. “Singapore’s Motorization Policies 1960-2000.” *Transport Policy* 8, 125-139.

45. Willoughby, 127.

46. Willoughby, 125.

47. For more insight on carsharing in developing countries, see Zegras, Chris, and Ralph Gakenheimer. 1999. “Carsharing in Latin America: Examining Prospects in Santiago;” also, “CarSharing: A Hammer for Sustainable Transport.” *Journal of World Transport Policy & Practice* 5:3, 158-175.

48. Articulated buses are extra-long buses that bend.

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52. Sathaye and Walsh, 208.

53. Sathaye and Walsh, 207.

54. National Research Council, 2.

55. United Nations Centre for Human Settlements (HABITAT). 1996, 279.

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57. The Kyoto Protocol is an agreement negotiated in Kyoto, Japan, in 1997 to strengthen commitments under the United Nations Framework Convention on Climate Change (UNFCCC). The Protocol sets binding emission targets for industrialized countries averaging a 5.2 percent reduction from 1990 levels by 2008-2012, and establishes market-based mechanisms that allow parties to meet their targets in part by trading emission allowances or sponsoring emission reduction projects in developing countries. The Protocol will enter into force when ratified by 55 countries, including countries accounting for 55 percent of carbon dioxide emissions from industrialized countries in 1990. The Protocol had not entered into force at the time of publication. The UNFCCC is one of three international agreements negotiated at the 1992 UN Conference on Environment and Development. The UNFCCC set a long-term objective of stabilizing atmospheric concentrations of greenhouse gases at a level that would "prevent dangerous anthropogenic interference with the climate system." The Convention called for industrialized countries to voluntarily return their GHG emissions to 1990 levels by 2000.

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(http://www.isr.gov.au/resources/energy_greenhouse/igp/); and Salon, Deborah. 2001. "An Initial View on Methodologies for Emissions Baselines: Transport Case Study." International Energy Agency. November.

60. Zhou et al.

61. O'Ryan et al.

62. National Research Council, 1996, 22.

63. Prozzi et al. 2002.

64. Gomez-Ibanez and Meyer, 24.

65. National Research Council, 4.

66. Bose et al.; Zhou et al; O'Ryan et al.; and Prozzi et al.

67. For instance, in Delhi, scooters and motorcycles with 50-150 cc engines cost as little as \$400 when new, and much less when used.

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