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Transportation

in Developing Countries

Greenhouse Gas Scenarios for Shanghai, China

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PEW CENTER
ON
Global CLIMATE
CHANGE

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Prepared for the Pew Center on Global Climate Change

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Contents

Foreword *ii*

Executive Summary *iii*

I. Introduction *1*

A. China: A Changing Nation *1*

B. Shanghai: A City in Transition *2*

II. Shanghai's Transportation Picture *4*

A. Transport Infrastructure: Plans and Investments *7*

B. Vehicle Ownership in Shanghai *8*

C. Motorization in the Coming Decades *10*

III. Policies and Strategies *14*

A. Air Quality and Energy *14*

B. Avoiding Gridlock *17*

C. Leapfrog Technology Opportunities *21*

V. Scenarios for the Future *23*

A. Greenhouse Gas Scenarios *23*

B. High Greenhouse Gas Emissions Scenario *26*

C. Low Greenhouse Gas Emissions Scenario *28*

V. Conclusion *31*

Glossary *34*

Appendix *35*

Endnotes *40*

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

The transportation sector is a leading source of greenhouse gas (GHG) emissions worldwide, and one of the most difficult to control. In developing countries, where vehicle ownership rates are considerably below the OECD average, transport sector emissions are poised to soar as income levels rise. This is especially true for China, whose imminent accession to the World Trade Organization will contribute to economic growth and could make consumer credit widely available for the first time. These factors are likely to accelerate automobile purchases, and GHG emissions.

Shanghai is one of China's most dynamic cities. Extremely densely populated, with very low personal vehicle ownership rates for its income level, Shanghai is also home to a nascent Chinese automotive industry. Transportation plans and policies there are designed to achieve broader urban objectives of population decentralization, with an eye to controlling increases in traffic congestion and improving environmental quality. Because Shanghai's transportation system and planning process are so sophisticated, Shanghai may be a "best case" for controlling transportation sector GHG emissions in the absence of climate change mitigation goals.

This report creates two scenarios of GHG emissions from Shanghai's transportation sector in 2020. It finds:

- Greenhouse gas emissions quadruple in the low-GHG scenario; they increase sevenfold in the high scenario. On a passenger-kilometer basis, the estimated increase ranges from 10 to 100 percent.
- Providing an array of high-quality options to travelers can help meet the demand for transportation services while keeping traffic congestion in check and meeting other urban objectives.
- Special lanes and other infrastructure to accommodate vehicles such as buses, minicars, and bicycles can save money and improve traffic circulation.
- Using clean technology and fuels in motorized vehicles lowers the environmental impact of various transportation modes.
- Perfecting the use of "intelligent" traffic control systems through improved coordination will yield higher returns on capital investments.

Transportation in Developing Countries: Greenhouse Gas Scenarios for Shanghai, China is the second report in a series examining transportation sector GHG emissions in developing countries. The report's findings are based on a Lifecycle Energy Use and Emissions Model developed by the Institute of Transportation Studies at the University of California at Davis, which estimates GHG emissions from the transportation sector.

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Executive Summary

Shanghai is experiencing rapid economic growth. Affluence is motivating dramatic and far-ranging changes in urban structure, transportation, and energy use. This report examines two transportation trajectories that Shanghai might follow and how they would affect greenhouse gas (GHG) emissions.

Shanghai's metropolitan population of over 13 million people continues to grow relatively slowly, but its economy is growing rapidly. The average annual per capita income is \$4,000, three times higher than the rest of China, and the Shanghai economy is expected to grow at more than 7 percent per year through 2020.

Massive new transport system investments planned for the next two decades are aimed at lowering Shanghai's extremely high population density, supporting economic growth, and enhancing the quality of life. The list of new investments is impressive: expansion of the new airport, construction of a deep-water harbor, three new bridges and tunnel river crossings, completion of a 200-kilometer modern rapid transit rail system, expansion of suburban highways, and construction of 2,000 kilometers of new and upgraded urban roads. These investments will improve the city's transportation system, but are costly and threaten greater energy use and air pollution. +

A central issue in Shanghai's development is the role of personal vehicles, especially cars. The city currently devotes little land to roads and has only 650,000 cars and trucks — very few of which are privately owned — placing vehicle ownership levels well below virtually all cities of similar income. Even with this small number of vehicles, Shanghai already suffers from serious transport-induced air pollution and traffic congestion.

Shanghai city planners project a quadrupling of cars and trucks in the city by 2020. This projected increase is premised principally on two factors. First is rapid income growth, which will make car ownership possible for a much larger segment of the population. And second is vehicle prices, which are likely to plummet due to China's imminent accession to the World Trade Organization (WTO). Lower prices will result from increased competition, compulsory reductions in vehicle tariffs, and easier access to consumer credit. +

These projected increases in vehicle use are not certain. Even apart from WTO membership, vehicle ownership and use — and GHG emissions — will be strongly influenced by three interrelated policy debates: industrial policy toward the automotive industry, air quality policy, and transportation and urban growth policy.

The city's decisions about vehicle use will be critical in shaping Shanghai's future. This report addresses the forces about to transform the transportation system of Shanghai, and examines policies and strategies that direct it toward greater economic, social, and environmental sustainability.

The two transportation scenarios draw upon extensive interviews with decision-makers and experts in Shanghai and Beijing. One scenario is premised on rapid motorization, the other on dramatic interventions to restrain car use and energy consumption, resulting in lower greenhouse gas emissions. Neither is a “business-as-usual” scenario, since this characterization is meaningless in a time of massive investments and policy shifts. Instead, these scenarios are meant to estimate likely upper and lower bounds of greenhouse gas emissions from Shanghai transport in 2020, taking as given the projected strong economic growth. If the economy grows more slowly, emissions will likely be lower than the scenarios indicate.

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The rapid motorization scenario is based on the projected quadrupling of cars by 2020, coupled with a substantial increase in population. It results in a sevenfold increase in GHG emissions. The restrained scenario results in a fourfold increase in GHG emissions. In this restrained scenario, almost all emissions growth is due to increases in travel, not increases in energy intensity or GHG intensity of travel. Emissions per passenger-kilometer increase only about 10 percent in the restrained scenario compared to a doubling in the rapid motorization scenario.

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Caution is urged in generalizing the findings of this report to other cities in developing nations. Shanghai is not a typical Asian city, given its surging economy and its world-class planning capabilities. However, the conditions for alternative transportation options are more propitious here than perhaps any other megacity of the world. If the city is effective at restraining growth in vehicle use (and GHG emissions), Shanghai may serve as a model for other cities in the developing world.

I. Introduction

China is in a period of rapid change, both economically and socially.

The future is difficult to predict under these circumstances. It is possible that the unique circumstances of China — and Shanghai in particular — will result in a different development path from that of other nations and megacities.

A. China: A Changing Nation

China's history, economy, and social institutions differ significantly from those of the western world. In terms of land area, China is roughly the same size as the United States, but with a population four times as large. Since China initiated its “open-door” policy in 1978, the country’s economy and society have undergone enormous change. Much more change is likely, with important implications for transportation and the environment.

Before 1978, China’s economy was centrally planned. Proceeds from business and agriculture were distributed to local governments and the people. The distribution was not always equal. Some parts of the country received substantially more than others. Populations did not migrate to follow resources because the system of local registration allocated housing, jobs, education, and other social benefits to individuals according to where they were registered. Although this registration system still exists, its impact has lessened because of the new larger role of the market system in providing basic goods and services. Expanded markets are giving people greater choice in what they consume, what jobs they hold, and where they live.

Unlike reform processes in many other economies in transition around the world, China’s economy has been changing gradually and economic growth has been steady. Between 1977 and 1998, the national economy grew approximately 10 percent per year,¹ with many functions of the planned economy gradually coming under the control of market forces. Over the next decade, strong economic growth is expected to continue, but at a slower rate of about 7 percent per year.²

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The overall effect of economic transformation and growth is unprecedented. The Chinese economy is increasingly a hybrid of a planned and market economy. Many of the formerly state-owned businesses and factories are now owned and operated by private companies and individuals.³ The viewpoint of decision-makers and individuals is also changing. One interviewee for this study said, "In China, if the government wants to do something, they will or can do it." But others are skeptical. In any case, the influence of the central government has dwindled dramatically. In China's new market economy, policy-makers have less direct control over the provision of goods and services than under the planned economy. Economic and industrial policy is evolving rapidly. Decisions made now will have far-reaching implications for transportation, energy use, and GHG emissions. Chinese policy-makers are looking cautiously to the rest of the world for successful policies that might work at home.

China's transport system is not a large source of greenhouse gases. At present, only about 7 percent of China's carbon dioxide (CO₂) emissions (the principal greenhouse gas associated with transportation) come from the country's transport sector, compared to about one-third in the United States.⁴ The percentage is about the same in Shanghai – 6.4 percent by one estimate.⁵ On a per capita basis, China's CO₂ emissions from the transportation sector were only 122 kilograms, about 3 percent that of the United States.⁶

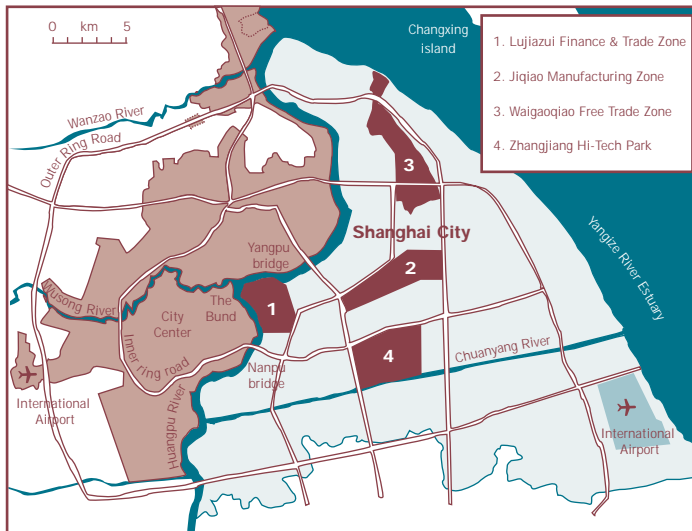
+ B. Shanghai: A City in Transition

*Thirteen million people reside in the 6,340 square kilometers of Shanghai, located on the eastern coast of China in the Yangtze River Delta.*⁷ The population density in the central city currently averages 22,700 people per square kilometer. The densest area exceeds 60,000 per square kilometer, roughly three times that of Manhattan.⁸

Much of the total land area is rural.⁹ The older urban area comprises 280 square kilometers, and a newly urbanized area on the opposite side of the Huangpu River covers another 130 square kilometers (see Figure 1). This makes the urban area of Shanghai about twice the size of Washington, D.C.¹⁰ Although the amount of developed urban area is rapidly expanding, city authorities expect the urban area to expand from 410 kilometers today to 1,100 square kilometers in 2010.¹¹

Figure 1

Map of **Shanghai**



Source: Recreated from Wu, Weiping, "City Profile: Shanghai," *Cities*, Vol. 16, No. 3, pp. 207-216, 1999 and Shanghai Map Publishing House, 1997.

Shanghai is one of only four cities in China to have the status of a province rather than a municipality. As a result, Shanghai has a higher profile and greater access to national funds than most other cities. Even so, infrastructure spending in Shanghai was low until the 1990s. Due to historical political considerations, the central government did not return a proportionate share of the large tax revenues collected in Shanghai. Housing was in bad repair, as was commercial and industrial space, and road capacity per capita was among the lowest in the world.¹²

These conditions have changed. Infrastructure funding from local and central government sources, domestic and foreign investment, and international loans has sharply increased.¹³ Massive construction of office and residential space, transportation infrastructure, and public utilities is underway.

This massive investment in infrastructure is due partly to the city's thriving economy. In 2000, Gross City Product (GCP) per capita in Shanghai was over \$4,000 (8.28 Yuan = U.S. \$1), three times higher than the rest of China.¹⁴ The city has grown faster than the national average, and is widely expected to exceed the nation's forecasted growth of 7 percent per year into the foreseeable future.¹⁵

A central feature of Shanghai's development plans is to reduce its high population density. The local planning authority is pursuing a plan of multi-centralization by building eleven new satellite cities to siphon portions of the population away from the dense core. Substantial relocation of industry to these cities has already occurred and many high-rise apartment buildings are under construction. Multi-centralization is not a unique phenomenon or goal; it is the de facto or formal planning strategy of most major cities around the world, though Shanghai is pursuing this goal more aggressively and deliberately than most.

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II. Shanghai's Transportation Picture

Despite rapid economic growth, vehicle ownership remains remarkably low in Shanghai. Meanwhile, the city has been investing huge sums in road and rail infrastructure, in part to support decentralization of the city. More infrastructure, satellite cities, and population dispersion will mean more cars, energy use, and environmental stress.

Shanghai's development has been shaped by its historical role as China's largest seaport. Railways, highways, inland canals, and ocean shipping lines meet here to exchange freight and passengers. Since the late 1970s, economic activity and intercity movement of passengers and goods has sharply increased. Shanghai's port handles 18 percent of the nation's exports, and ranks sixth in the world in capacity.¹⁶ With the booming economy, the seaport is becoming busier. Land delivery of goods through Shanghai's urban transport system is also increasing. As almost everywhere else in the world, highway transport of passenger and freight has increased faster than railway and sea transport, and airline transport has increased fastest of all. Thus, both passenger and freight transport in Shanghai have gradually shifted to more energy-intensive modes.¹⁷

Intracity travel, on the other hand, has relied on modes of travel that consume very little energy. Until about 1990, almost all travel was by foot, bicycle, or bus. Cars, scooters, and motorcycles were rare.

Over the last two decades, bicycles have gradually increased their role, replacing walking, and buses have continued to account for a large share of passenger travel. By the end of the 1980s, Shanghai reportedly had the largest urban bus system in the world, and the number of riders was still increasing. But limited funding was leading to lagging investments in network expansion, bus amenities, and service frequency. This deterioration of service, combined with increased income of individuals, led to other more personalized modes becoming relatively more attractive.

Shanghai responded in the 1990s in a number of ways. To restrain large and growing bus subsidies, Shanghai introduced competition into the bus supply system. Other cities in China did the same, but Shanghai pursued change more aggressively than most. In Shanghai the municipal bus company was

deregulated and several independent operating companies were created to compete for operating concessions. Bus data from different sources conflict, but all indicate that Shanghai continued to have the largest bus system in China through the 1990s, though passenger volumes were shrinking.¹⁸

Shanghai planners anticipate renewed growth in bus travel in the coming decades, with ridership doubling by 2020. They expect that the bus industry will be strengthened by continuing reforms and that new road infrastructure will be built to serve buses. Plans include building six elevated busways to facilitate bus travel in congested areas.

Planners expect the doubling of bus ridership, in part because of a large overall increase in passenger travel. Residents started traveling more and further in the 1980s and increasingly so in the '90s — not only due to income growth, but also industry relocation. The movement of factories from the central city to the periphery created long commutes for many workers. Because the newly developed areas were not densely populated, and therefore not profitable to serve, bus companies provided limited service. Because the commuting distance was often too far for bicycles, motorized two-wheelers (scooters and small motorcycles) became a popular mode of travel.

The automobile population in Shanghai is well below the world average for cities of similar GCP per capita. The vehicle population began to expand in the 1990s, increasing from 300,000 to 600,000 between 1990 and 1998,¹⁹ reaching about 650,000 in 2000. Most of these vehicles are owned by businesses and governments. About 40,000 are taxis, and only about 15,000-50,000 are owned by individuals.²⁰ The city government controlled new vehicle registrations with a high vehicle registration fee through 1998. The city has used an auction system for vehicle registrations since then.

Even with the small vehicle population, the streets are congested — the result of high population density, many pedestrians and bicycles, and limited road infrastructure. Bicycling and walking are the primary means of travel, together comprising over 60 percent of total trips taken in 1995 in Shanghai.²¹ Shanghai residents own 6-7 million bicycles (roughly one for every two residents), plus 250,000 scooters and small motorcycles, and about 500,000 mopeds.²² The scooter and motorcycle population is declining because of new restrictions on the registration of new scooters and other vehicles with two-stroke engines. These restrictions are premised on air pollution and safety concerns. This decline may be temporary. As incomes increase, travel patterns disperse, and cleaner-burning four-stroke engines (and perhaps battery-powered two-wheelers) become available, sales of motorcycles and scooters are likely to surge.

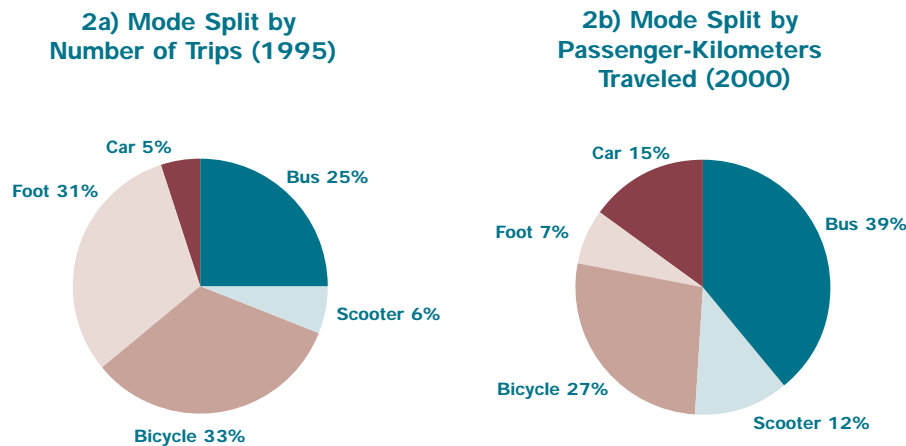
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Because most walking and bicycling trips are short, measuring the modal split by passenger-kilometers traveled paints a different picture than measuring it by number of trips, as indicated by Figure 2.²³ Motorized travel now accounts for about two-thirds of all passenger-kilometers traveled. Around two-fifths of that motorized travel is by car and motorized two-wheeler.²⁴

Figure 2

Travel Mode in Shanghai



Sources: Ximing Lu, Xiaoyan Chen, and Xuncu Xu, *Urban Passenger Transport Planning and Urban Development*, Shanghai City Comprehensive Transportation Planning Institute, East China Polytechnic Publishing House, 1996; and Shanghai City Comprehensive Transportation Planning Institute, *Metropolitan Transport Comparative Study*, Shanghai report for the United Nations Centre for Regional Development, 1997. Year 2000 mode split by passenger-kilometers was estimated by authors.

Although the absolute number of vehicles is still relatively small, traffic congestion and air pollution are becoming severe. By 1993, transportation accounted for most of Shanghai's urban air pollution, contributing an estimated 90 percent of carbon monoxide, 92 percent of volatile organic gases, and 23 percent of oxides of nitrogen (NO_x) emissions. In 1996, monitoring data indicated that transportation accounted for 56 percent of NO_x emissions.²⁵

To limit air pollution and traffic congestion, city officials began capping the registration of all new cars and trucks in 1998 at 50,000 annually.²⁶ The government also limits ownership of motorized two-wheelers. In 1996, Shanghai capped the registration of mopeds (under 50 cc), allowing owners to transfer registrations to new mopeds but not to purchase additional mopeds, and soon after banned the use of all scooters and motorcycles (over 50 cc) from the city center. The only unrestricted motorized vehicles are two-wheelers powered by batteries, but few of these are available.²⁷

These motorcycles and scooters are unlike those seen in the United States and most of western Europe. They are very small with inexpensive two-stroke engines that are inefficient and highly polluting. Most are 50 to 150 cc, much smaller than most scooters and motorcycles available in the United States.

Restrictions on motorized two-wheelers are due not only to high emissions and noise. These vehicles are also perceived as unsafe because they mix with slower bicycles and are often driven aggressively by young men. The government views these vehicles as part of the early stages of economic development which they will soon pass through — a view based largely on the rise and then near-disappearance of scooters and motorcycles in western Europe.

A more complex problem confronting Shanghai is traffic congestion. Serious congestion is relatively new. The problem is quite different from that of most U.S. cities, mainly due to the large number of bicycles and pedestrians sharing the roadways with cars, motorized two-wheelers, and buses. Even freight movement is sometimes performed by bicycle in Shanghai. There is limited road space because land is intensively used for other purposes, making traffic congestion an endemic problem.

A. Transport Infrastructure: Plans and Investments

Shanghai has responded to pressure on the urban transport system with massive infrastructure investments. From 1991 to 1998, about 14.6 percent of the GCP was devoted to construction — and a significant percentage of that for transportation, a much higher rate than is typical for developing country megacities. The surface area of paved roads increased by 62 percent.²⁸ In 1993, Shanghai spent three times more money on urban construction and maintenance than any other Chinese city, about half on roads, bridges, and mass transit.²⁹ From 1991 to 1996, Shanghai spent approximately \$10 billion on transport infrastructure, including two major bridges, a tunnel, an inner ring road, and the first line of its new subway system. Jianping Wu writes, “The pace was something like building the Brooklyn and Manhattan bridges in New York and the Lincoln and Holland tunnels between New York and New Jersey all in five years.”³⁰ Shanghai has plans to continue with intensive infrastructure investments, building both additional roadway infrastructure, and public transit infrastructure.

The major motivation for this burst of activity was to fill the transport infrastructure deficit resulting from decades of deferred investment. By 2000, the projects from the first plan were completed and the local government declared that the infrastructure deficit no longer existed.³¹

The second phase of the urban transport planning effort began in 1995. It is aimed at moving housing and industry outside the city center to decentralize the metropolitan region. Shanghai's Land Use Master Plan predicts for 2020 a population of 16 million, a multi-center metropolis with a strong central business district, a new city center in Pudong New Area on the east side of the Huangpu River, and eleven satellite towns, all linked by an efficient transport network.³²

The second plan also calls for three Huangpu River crossing facilities, a second runway for the new international airport, a new deep water harbor for container ships, 200 kilometers of rail (of which 60 kilometers were completed by 2000), six elevated busways, and 650 kilometers of divided highway in suburban areas (of which 520 kilometers will be new).³³ Roads serving the intercity network will charge tolls. The new rail system will be largely underground and is forecast to carry 8 million passengers per day by 2020.

B. Vehicle Ownership in Shanghai

The most striking aspect of Shanghai's transport system is the small number of cars and the rarity of private vehicle ownership. As indicated earlier, Shanghai has only about 15,000 to 50,000 privately owned vehicles. Beijing, with similar income and population, has 10-20 times more. Even in terms of the number of total vehicles, Shanghai has fewer than most cities of comparable wealth. Shanghai has several times the income of Delhi, for instance, but less than half the number of private vehicles (see Table 1).

Table 1

Vehicle Ownership and Other Characteristics for Selected Cities

City	Year	Population	Gross City Product per Capita	Vehicles per 1,000 Persons*	Passenger Cars per 1,000 Persons
London	1990	6,679,699	\$22,215	356	288
Paris	1990	10,661,937	\$33,609	383	338
Tokyo	1990	31,796,702	\$36,953	266	156
Delhi	1998	13,400,000	\$850	200	63
Shanghai	2000	13,000,000	\$4,000	69	22

Sources: Kenworthy and Laube, *An International Sourcebook of Auto Dependence in Cities 1960-1990*, 1999. Delhi data are mostly from Bose et al., *Transportation in Developing Countries: Greenhouse Gas Scenarios for Delhi, India*, Pew Center on Global Climate Change, Arlington, VA, 2001.

* Includes motorized two-wheelers in the cases of Shanghai and Delhi, but excludes mopeds. About 40 percent of four-wheel vehicles in Shanghai are passenger cars, but this ratio is expected to increase soon to about 70 percent.

The scarcity of privately owned cars is related to issues of access, cost, ease of use, and quality. First, it is expensive and time-consuming to acquire a driver's license.³⁴ One must enroll in an official driving school at a cost of \$500, a significant expense for the typical Shanghai resident. The course involves three weeks of classroom sessions, more than a month of behind-the-wheel training, and three separate road tests.

Second, it is very expensive to own and operate a car in Shanghai.³⁵ Fuel prices are similar to those in the United States, and parking costs \$1-3 per hour in downtown Shanghai. The greatest barrier is purchase price. According to the exchange rate (8.28 Yuan = U.S.\$1), the sales price of a small, domestically produced sedan is equivalent to approximately \$10,000. The actual price is much higher. A tax of approximately 10 percent and a large local registration fee must be paid at the time of purchase. Until 1998, the registration fee was approximately \$20,000 on new cars. Under pressure from the central government, the city discarded the high fees and created a vehicle registration auction similar to the one used in Singapore to limit the number of new vehicles that could be registered.³⁶ In early 2000, the auctioned registration fee was approximately \$2,500.

For imported cars, the cost is even higher, due to extremely high tariffs. In November 1999, China and the United States signed a World Trade Organization (WTO) accession agreement that cut tariffs of 80-100 percent on imported cars (varying by type and price of vehicle) to 25 percent by 2006. +

Cost is a barrier, not only because it is high relative to average incomes, but also because consumer credit is not yet widely available in China. This means that a prospective car owner must pay the full amount upfront. This outlay remains beyond the reach of virtually all families. In addition to reduced tariffs on imported cars, WTO accession will require opening up the financial services market, which should lead to easier access to consumer credit. The result would be much greater ease in purchasing vehicles. However, it remains uncertain the extent to which consumer credit will in fact become more available, and the extent to which Chinese consumers will embrace buying on credit. +

A third deterrent to car ownership is limited road infrastructure and traffic congestion. Land use patterns in Shanghai evolved before motorized transport. The city grew in a very densely developed radial pattern, with narrow streets conducive to bicycle use and pedestrians. Services, schools, and jobs are well mixed with housing and within easy bicycling distance for most people. Because trips are generally short

and bicycles and public transit both widely available, cars bring little extra value for everyday travel. For intercity travel, options include train, bus, or airplane. Road touring vacations are rare in China.

The fourth explanation for low private vehicle ownership rates is the relatively low quality of vehicles that have been available for sale. The tariffs on imported cars are aimed at protecting the fledgling domestic auto industry, giving substantial market power to local producers. The result is elevated prices for products that are often technologically outdated. Most vehicles have been produced by joint ventures between major international automakers and local companies, many using technology from the 1980s.

C. Motorization in the Coming Decades

Pressure for increased private auto ownership in Shanghai comes from several sources: income growth, car economics, social status, population growth, and population dispersal.

Car economics, and therefore car sales, are affected by government policies in a number of ways. One is through national industrial policy. In 1994, China designated automotive manufacturing a pillar industry of the economy, initiating a major debate, still underway, over the extent to which the government should promote automotive manufacturing (see Box). Shanghai is deeply engaged in this debate since it is a major industrial center and already home to several of the largest automotive manufacturing facilities in China.

In 1994, Chinese leaders established a national goal to produce 1.2 million cars per year by 2000, and 3.5 million per year by 2010, with 90 percent of output sold domestically. The policy encouraged private car ownership, eliminated government control of vehicle purchases, reduced taxes, and allowed the marketplace to determine car prices.³⁷ However, actual production in 2000 of about 0.7 million fell far short of the 1.2 million goal.³⁸

The Pros and Cons of Automotive Manufacturing as a "Pillar" Industry

Many Shanghai policy-makers argue that the auto industry should become one of the "pillar" industries of the Chinese economy. A thriving auto industry will bring economic prosperity and an improvement in the standard of living in Shanghai. It will bring jobs and money. Not only will it generate direct employment in car factories, but it will also stimulate investments in a wide range of other supplier industries, including rubber, glass, steel, plastics, and machine tools.

In addition to the economic prosperity that would come to Shanghai with a booming auto industry, widespread car ownership would transform lifestyles and land development. It would become possible for Shanghai citizens to live in comfortable homes away from the crowds and pollution of the central city. Residents would enjoy much greater freedom of movement, not only within Shanghai, but also by being able to travel with greater ease outside the region.

On the other hand, automotive manufacturing does not have the same export growth opportunities as telecommunications and electronics. And there are many drawbacks to creating a major car industry. First, it would create a strong political force for a large domestic market that would lobby for reduced automotive restrictions and taxes. This would make it ever more difficult to manage growth in vehicle ownership. Second, more cars would bring sharp increases in energy use, pollution, and traffic congestion. Third, many Chinese cities, especially Shanghai, are exceptionally dense and ill-suited to cars. Fourth, valuable farmland surrounding the city would be consumed by new roads and urban sprawl, encouraged by widespread auto ownership. Fifth, the sense of community in Shanghai would be strained by the widening gap between haves and have-nots, leading to greater tensions, more physical separation, and less cohesion. And sixth, more cars would require huge increases in public funds for road and parking infrastructure, resulting in a diversion of funds from other uses, including mass transit.

During the late 1990s, nearly every province, including Shanghai, encouraged local investment in the auto industry. The result was excess capacity and a plethora of small, inefficient companies. Many local governments have given up their earlier ambitions, but several joint ventures between local companies and international automakers did progress. These companies now have the capability to bring the latest technology and products into China, although they have used outdated technologies until now.

Though Shanghai never articulated a clear strategy, policy-makers presumed that the auto industry would be a boon to the local economy. Shanghai has been particularly aggressive and successful in this regard. By 2000, auto-related production accounted for 20 percent of GCP.³⁹ Shanghai is home to Shanghai Automobile Industry Company (SAIC), a joint venture with Volkswagen producing over 200,000 cars, and recently attracted a large new joint venture with General Motors that began production in 2000 and is building a large manufacturing complex. The GM joint venture company is also exploring production of simple, inexpensive "farm cars," designed for rough terrain operation in rural areas.

Some observers suggest that consumers have recently been deferring their car purchases, partly in anticipation of better and less expensive cars becoming available after China's accession to the WTO. Dramatic increases in car buying would be assured in coming years. Some of the barriers that deter private car ownership in Shanghai are already being lifted. World Trade Organization membership will result in higher car quality and, barring new taxes, lower car prices. Given the huge population and rapid income growth, foreign automakers and part suppliers are expected to enter the Chinese market in an aggressive manner. This intensified competition, along with the increased availability of consumer credit, will be a strong force for increased car ownership.

Beyond economics, a second reason to expect increased car ownership in Shanghai is status. The private car is both a personal and a national symbol of status and success. Many Chinese believe that when more people own cars in China, the status of the entire nation is elevated in the eyes of the international community. This view of the car as a status symbol is not unique to China.

A third explanation is population dispersal. Shanghai's multi-centralization policy will reduce density in the city center by creating multiple urban centers around the periphery. This decentralization will lead to longer trip distances, reducing the attractiveness of walking and bicycling while enhancing the attractiveness of private vehicles.

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A fourth explanation for vehicle growth is population growth. Shanghai is an affluent city and an attractive destination for many Chinese seeking a better life.

Shanghai has powerful local institutions that can effectively manage growth in the number of vehicles on the road. The extent to which they restrain growth in vehicle ownership and use will depend largely on evolving perceptions about the desirability of motorization and larger national policies. The national government continues to pursue a strategy to make the auto industry a pillar of the national economy. In 2000, in support of this strategy, the central government announced that 238 vehicle fees were being eliminated.⁴⁰

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Another important, though often ignored, element in the debate over automotive industry investments is motorized two-wheelers. They are often ignored for three reasons. First, China already has a large two-wheeler manufacturing industry which produces roughly half of all motorized two-wheelers in

the world. Second, motorized two-wheelers require much less investment and manufacturing and engineering capability than cars. Third, as indicated earlier, Chinese policy-makers see large-scale use of motorized two-wheelers as a relatively brief phenomenon in the development process of the country, much as occurred in western Europe.

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III. Policies and Strategies

This section examines air quality, energy, and transportation strategies already being pursued in Shanghai, and prospective strategies for the future. The initiatives outlined here will help resolve Shanghai's transportation problems, and should also significantly reduce GHG emissions from the transport sector.

A. Air Quality and Energy

Shanghai's air pollution is increasingly due to transportation. In the past, air pollution problems came from heavy industry located within the city. Most of these factories have been relocated to surrounding areas, partly to clean up Shanghai's air. Now, as indicated earlier, a substantial portion of Shanghai's remaining air quality problem comes from the transport sector, despite relatively few motorized vehicles in the city.⁴¹

The transport sector has become a focal point for air quality issues in many urban areas in China. The national government has recently implemented a number of stringent regulations aimed at limiting air pollution from urban transportation. Among the new pollution regulations implemented in China are vehicle emissions standards, mandatory inspection and maintenance programs for vehicles in certain cities, and gasoline quality standards. The new vehicle emissions standards are ambitious, equivalent to the "Euro I" standards that first took effect in Europe in October 1993 and in the United States in the early 1980s. The gasoline quality standards include a nationwide ban on leaded gasoline, effective January 2000, which apparently is being observed and enforced. However, sulfur levels remain very high in both gasoline and diesel fuel, which impedes the introduction of advanced emission control technology.

Shanghai's city planners have been environmental leaders in China. Air pollution is less severe in Shanghai than in many other Chinese cities. Along with several other large cities, in 1998 Shanghai began eliminating leaded gasoline ahead of the national government. In July 1999, again ahead of national requirements, the city promulgated new emission standards for other pollutants and, in the late 1990s, began switching many vehicles to cleaner-burning liquid petroleum gas (LPG) and compressed

natural gas (CNG). The taxi fleet is currently being retrofitted to burn LPG, and the bus fleet is being retrofitted to burn CNG. The first CNG fueling station in Shanghai opened in October 1998.

The principal air quality and energy strategies of Shanghai and the nation are examined here for their relevance to GHG emission reduction. Pollutants that cause reductions in local air quality are largely different from gases that contribute to global warming. In fact, many of the initiatives undertaken in Shanghai to combat air pollution have little or no direct impact on GHG emissions. Some, especially those related to altering engine combustion processes or adding after-treatment devices, can even cause a minor increase. However, as indicated below, other vehicle-related strategies can provide large GHG emissions reductions, and any strategy aimed at managing demand will generate large GHG emission benefits.

Air quality initiatives such as those described here, including those aimed at alternative fuels, are relevant to GHG strategies on several levels, even though they often have little direct effect on GHG emissions. These air quality initiatives are important because air quality tends to be a strongly compelling, popularly embraced goal. GHG reduction is not. Initiatives to reduce air pollution build environmental consciousness and strong constituencies that carry over to other environmental goals. Moreover, some greenhouse gases are also air pollutants, and air pollutants are often not distinguished from greenhouse gases in the public mind.

Some believe that widespread use of alternative fuels such as natural gas may be a leading strategy to help solve China's environmental problems.⁴² Indeed, CNG combustion results in much lower air pollutant emissions than gasoline or diesel combustion. However, the effect on greenhouse gases is not as dramatic. The use of CNG in spark ignition engines in place of gasoline results in about a 20 percent reduction in GHG emissions. However, in diesel engines, CNG provides little or no benefit and can even increase emissions.⁴³

In addition to its air pollution benefits, CNG is embraced for its low cost and energy security benefits. China has larger domestic supplies of natural gas than petroleum, and Shanghai has access to gas from the East China Sea as well as northwest China. Little natural gas is used today in China, but the country plans to exploit domestic sources and import liquefied natural gas (LNG). An LNG pipeline from northwest China to Shanghai is scheduled to be completed in 2007.⁴⁴

China has relatively modest supplies of petroleum, despite intensive exploration efforts in recent years. It has about 2 percent of the world's proven reserves, but 20 percent of the world's population. In

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2000, imports supplied about one-fourth of domestic oil needs. With domestic production growing 1.9 percent from 1995 to 2000 and demand increasing 5.3 percent during the same period, oil imports continue to increase at a rapid rate. This gap could be mitigated by increasing investment in the oil industry by international companies and on-going reforms of the domestic industry that together could lead to significant increases in domestic production.⁴⁵

The two-stroke scooters and motorcycles are the principal source of vehicular pollution in Shanghai. New registrations for these vehicles have not been granted since 1996, but their population remains high since old registrations can be transferred to new vehicles. The city has recently begun to promote electric scooters as an option for residents who want the convenience of a new scooter. Motorized two-wheelers are particularly attractive in Shanghai as a means of personal transport because they are faster than bicycles, affordable for many, and easier to park than cars. Several electric scooter companies have established service and battery exchange networks for their customers to increase convenience.⁴⁶ Electric scooters provide huge air quality benefits and are far more energy efficient than existing scooters. However, electric scooters tend to have comparatively modest GHG emissions benefits because 75-80 percent of electricity in the country is generated from coal. Table 3 shows that on a full energy cycle basis, electric scooters in China generate about 20 percent less CO₂-equivalent emissions per vehicle-kilometer than four-stroke engine scooters, and less than half that of two-stroke scooters, though these differences may shrink over time as technologies improve. If the electricity were generated from natural gas or another non-coal source, much larger reductions in GHG emissions would result.

In summary, the drive to improve air quality is largely consistent with the drive to reduce GHG emissions. It provides a major impetus to restrain motorization and it motivates the commercialization of electric-drive propulsion technologies that use fuel cells, batteries, and hybridized combinations of electric motors and small internal combustion engines. These technologies are very clean and energy efficient. Hybrid-electric technologies reduce energy consumption by up to 50 percent; fuel cells may lower consumption even more. If low-carbon fuels are used, the GHG reductions are even greater.

B. Avoiding Gridlock

The key question is, Can Shanghai continue to manage the growing desire for personal vehicles?

Shanghai faces a difficult challenge in expanding its transport system. Increasing affluence and falling car prices lead to rapid motorization superimposed on a dense city that has minimal road capacity. Without exceptional investments, management, and policy intervention, the city could quickly become gridlocked.

Serious traffic congestion is a relatively new problem for Shanghai. The problem is quite different from traffic in most U.S. cities, mainly due to the large number of bicycles and scooters sharing the roadways with buses, cars, and pedestrians. The roadway system is also quite distinct, with much of the city having narrow streets originally built for pedestrians and bicyclists. A variety of policies and investments aimed at meeting Shanghai's transportation challenge are already in place. The vehicle population is controlled using a monthly auction system for new vehicle registrations. Freight movement by truck in the central city is restricted during the daytime when passenger travel demand is highest. One hundred thirty kilometers of expressway have been built in the past decade, with another 520 kilometers planned.⁴⁷ Substantial investments have been, and continue to be made, in public transit, including a new subway system that opened its third line in 2000.

Transportation is a central concern in Shanghai. A poorly managed transport system can hamper economic growth by creating costly, long, and erratic connections. A well-managed system reduces costs and eases access, and is fundamental to a growing economy.

Bicycle Infrastructure

Bicycles produce no pollution and are an inexpensive form of transport, but they are uncomfortable in bad weather, can be unsafe, and are unsuitable for some people. Bicycles use road space more efficiently than cars, but less efficiently than buses.

One means of making the best use of existing road space is to separate traffic operating at different speeds. Bicycles greatly slow motorized traffic if they share road space. From the bicyclists' point of view, sharing the road with motorized traffic can be quite dangerous. On most streets in Shanghai, bicycles and small scooters are separated from the flow of buses and cars with wide bicycle lanes. These lanes are used heavily, improving safety and lessening traffic congestion. Nevertheless, traffic delays occur where these lanes cross intersections (where turning bicycles and cars disrupt traffic flow).

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Figure 3

Exclusive Bicycle Lane in a newly developed area in Shanghai



Photo taken by author (Dr. Zhou) in Shanghai

Where bicycle use is light, this would not be a problem. In Shanghai, however, this situation can cause significant delays. During busy times of the day, it is common to see more than 50 bicycles and scooters stopped at a red light. At some intersections in Beijing, separate

traffic signals have been installed for the two sets of vehicles, but it is not clear that signals improve traffic flow in these cases. Other strategies under consideration are bicycle-only streets,⁴⁸ and intersection overpasses for bicycles and pedestrians.

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Information Technologies for Traffic Management

On congested links, even minor accidents or adverse weather conditions can be highly disruptive. The increasing availability of low-cost information technologies now makes it possible to monitor and manage traffic flow in real time. In the mid-1980s, Shanghai began installing advanced traffic coordination systems. Approximately 1,000 intersections are now monitored, and 18 different systems are controlling surface and elevated roads, tunnels, bridges, and subway rail lines.

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Unfortunately, these systems are not efficiently linked and traffic information is not shared among different systems. The city is planning to correct this situation within the next five years through development and implementation of an integrated traffic coordination system.⁴⁹ The result should be improved efficiency, especially via timed signal lights and rapid removal of vehicle breakdowns. But with widespread congestion and growing travel demand, more fundamental vehicle restraint strategies must accompany advanced traffic management.

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Restraining Use of Full-size Private Cars

To restrain use of full-size private cars, policy-makers must focus on car purchases. The fixed costs of using a private car for transport are much higher than the associated variable costs, such as tolls and parking fees. Once a person owns a car, much of the price of transportation has already been paid. A car owner will often choose to drive even when convenient and inexpensive alternatives exist. The most effective way to avoid this situation is to offer attractive transportation alternatives and raise the variable costs of vehicle use to reflect environmental and other associated costs. Existing policies include stringent and expensive driver licensing and vehicle taxes, limited car and truck bans, expensive downtown parking, and inexpensive taxis.

Shanghai might build upon these existing initiatives in a number of ways. A relatively inexpensive but effective option is the creation of strategically placed car-free zones during peak periods in areas well-served by public transit. Car traffic would be banned (with the possible exception of taxis) in designated areas during peak travel periods. In many parts of the world, this type of policy would be difficult to implement due to substantial car-oriented infrastructure capacity and high car ownership levels. Car owners, being the wealthiest and most powerful residents, would use their political and economic power against the proposed policy. However, China's centralized decision-making structure is relatively more resistant to such pressures.

In 1997, a car-free zone was introduced on Nanjing Road, the main shopping street in Shanghai. At first, the zone was car-free only on weekends, but with the recent construction of an underground rail transit station in the area, car-free restrictions were extended to weekdays as well. Shanghai has also implemented a similar policy on freight traffic. According to Shanghai traffic signs, between 7 a.m. and 7 p.m., heavy freight traffic is banned from the central city. This practice is common in many large Chinese cities.⁵⁰ With these precedents, local leaders are likely to accept the creation of more extensive car-free areas in Shanghai during peak periods.

Another policy might be to charge high parking fees, with fees highest in the densest areas, coupled with limitations on parking space. This strategy is already being pursued to some degree in Shanghai, where parking fees are extremely high compared to the average income of a Shanghai resident.

Improving Alternatives to Full-sized Private Cars

The most obvious alternative to the private car is public transit. Shanghai has been investing heavily in public transit in recent years, overhauling the bus system, and constructing an ambitious 200-kilometer heavy rail metro system. The city is also building high-rise apartments and bicycle parking lots near new rail transit stations. The convenience of Shanghai public transit is enhanced with an integrated electronic fare-collection system. As of 2000, people have been able to ride all modes of public transit in Shanghai, including buses, rail, and ferry boats, with one transit card.⁵¹

Figure 4

Bicycle Park-and-Ride Lot at a Shanghai Rail Transit Station



Photo taken by author (Dr. Zhou) in Shanghai

Another alternative to the full-sized private car is a smaller private vehicle. Many large auto manufacturers around the world are developing and selling very small cars for crowded city use. In Japan, about one-quarter of new vehicle sales have long been minicars (defined as having engine capacity of less than 660 cc). These vehicles are not suited to long-distance or high-speed travel, but function well for urban use. They are typically about half the size of a conventional sedan. New, inexpensive models under development are often referred to as “China cars,” indicating the automakers’ anticipation of a large market in China for small cars.

Scooters and motorcycles also economize on road space while providing many of the benefits of a personal car. Government policies could favor the use of minicars and electric scooters over conventional sedans by providing preferential parking and imposing reduced fees and relaxed vehicle registration fees.

Another option that would limit cars on the road is car sharing. This new form of car ownership is becoming popular in Switzerland and Germany.⁵² In Shanghai, car sharing could become the main method of accessing full-sized vehicles for the general population. In car sharing organizations in Europe and in the United States, members pay a yearly fee plus a charge per hour of use and per kilometer or mile of travel. These fees cover all expenses associated with owning a vehicle including insurance, maintenance, and fuel.

Good traffic management together with Shanghai’s planned infrastructure investments and a forward-thinking approach to vehicle policy could make Shanghai’s transport system a world-class model. Shanghai has an opportunity to develop an economical, environmentally friendly, and socially equitable transportation system that provides superior access to goods and services.

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C. Leapfrog Technology Opportunities

Leapfrog technologies are advanced technologies that allow developing countries to go beyond what is now typically used in developed countries. Developing countries could leapfrog pollution problems and other pitfalls that industrialized countries have encountered on their development paths.

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The GHG emissions scenarios in this report include a set of leapfrog strategies and technologies that are well known, but rarely implemented. Various leapfrog technologies are possible, such as fuel cells. Fuel cells provide the promise for very low air pollution and GHG emissions and high energy efficiency. Even more innovative solutions are possible, though not specifically targeted in the scenarios. They include automated rapid bus transit systems in which groups of buses operate on a network of

specialized lanes — an enhancement of the already contemplated elevated busway system. These buses could branch off at either end of a line to collect and deliver riders in less dense areas.

Likewise, small cars with small battery packs and/or fuel cells could operate on an electrified road, perhaps under automated control. The cars would gain power from the roadway, either from conductive or inductive electricity transfer.⁵³ With automated control, the capacity of the roadway would be very high (because lanes are narrow and headway distances between vehicles very small). The vehicles would veer off from the automated, powered roadway at the beginning and end of their trip.

These dual-mode car and bus systems might prove highly efficient from an economic and environmental perspective, and provide high quality service. Except for full vehicle automation, these technologies are technically well within reach of current engineering capabilities. They have not been implemented largely because of an array of financing and institutional issues. In developed cities, the cost and challenge of retrofitting the existing road infrastructure is daunting. In developing cities, where less infrastructure is in place, there is an opportunity to design the transportation system to accommodate these technologies. Given China's enormous population and growing wealth, it may be the time and place to pursue these revolutionary concepts.

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IV. Scenarios for the Future

Vehicle ownership and use will soar in Shanghai under any plausible scenario. With more vehicles and travel come more GHG emissions. But the emissions increase is highly sensitive to several powerful influences. GHG emissions are not necessarily locked into a fixed relationship with motorization or even energy use.

Energy consumption is related to the number of vehicles, but the nature of the vehicle and engine system can result in very different energy consumption per vehicle. Vehicles can be large sedans or small minicars, and they can use relatively inefficient conventional internal combustion engines, or highly efficient advanced diesel engines and fuel cells. A small, efficient vehicle, for instance, would consume as little as one-tenth as much energy as a large, gas-guzzling sport utility vehicle.

Likewise, GHG emissions are related to energy consumption, but depend on what fuels are used. For instance, the replacement of gasoline with natural gas in typical spark ignition engines would result in about a 20 percent reduction in GHG emissions, even accounting for methane emissions and the additional energy expended in compressing or liquefying the gas so that it can be stored compactly in a car. The use of diesel fuel in place of gasoline in cars would also reduce GHG emissions, and biomass fuels could eliminate almost all GHG emissions (assuming they are made from cellulosic materials grown, harvested, and processed in an energy-efficient manner). Electric vehicles can also result in much lower emissions if the electricity is not produced from carbon-rich coal. In the most extreme case, fossil energy use and GHG emissions could be almost completely eliminated — without changing car ownership levels — by substituting non-fossil energy sources.

A. Greenhouse Gas Scenarios

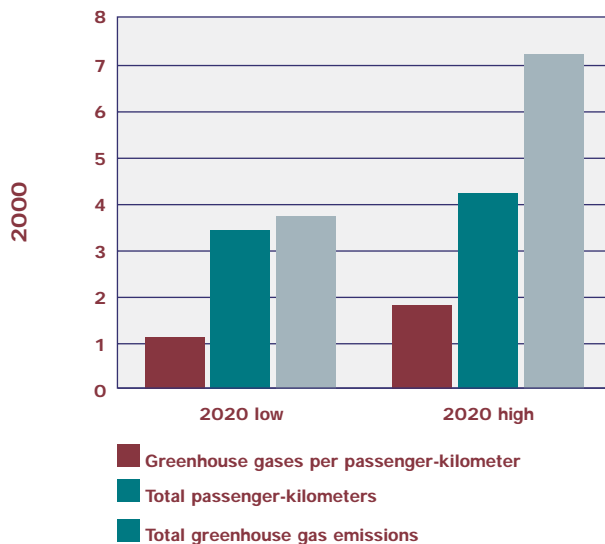
Exactly how Shanghai develops will have far-reaching implications for human activity and GHG emissions. Two scenarios of Shanghai's transport future in 2020 are postulated, reflecting high and low GHG emissions. Each is motivated by a different set of political, economic, and environmental conditions. Controlling GHG emissions is not the motivating factor, but is one outcome.

Scenarios are commonly employed to deal with complexity and uncertainty in forecasting. Ideally, one generates relevant information using credible research methods and objectively analyzes it with alternative scenarios of the future that provide upper and lower bounds on a plausible range of future emissions. The scenarios reflect realistic, but often quite contrary, descriptions of prospective development paths. This approach can provide a useful context for the development of “no regrets” public policy and business strategy.

To generate scenarios, the authors interviewed Chinese transportation experts and political leaders in Shanghai and Beijing in December 1999. The authors analyzed historical data and examined various options and strategies. The two scenarios generated are both premised on consensus forecasts of strong continued economic growth. If economic growth were faster or slower, emissions would be higher or lower than indicated by the scenarios. However, since this report does not address economic policy, economic variables were not considered.

Figure 5

Greenhouse Gas Emissions in 2020 from Passenger Transport in Shanghai (Compared to 2000)



Since reducing GHG emissions is unlikely to be a motivation in the foreseeable future in Shanghai, change and government action will be driven by other concerns.

Even under the most conservative circumstances and assuming continued economic growth, increases in vehicles, energy use, and GHG emissions will be rapid. In the restrained, low emissions scenario, cars increase their share of total kilometers traveled from 15 to 38 percent between 2000 and 2020; mass transit, motorcycles, and scooters maintain their

current share; and walking and bicycling drop considerably. Pollution, energy use, and greenhouse gases are restrained in this scenario by using cleaner fuels and more energy-efficient technologies. The net

result in this case is a fourfold increase in GHG emissions, with emissions per passenger-kilometer increasing only about 10 percent (see Figure 5).

The chief cause of these large absolute increases in GHG emissions is a dramatic increase in travel and personal vehicle use. These large increases in emissions start from a very small base. Transport currently accounts for only about 6 percent of Shanghai's total emissions.

Neither scenario is meant to be a "business-as-usual" scenario, since that characterization is meaningless in this period of massive investments and policy shifts. Instead, these scenarios are meant to provide upper and lower bounds on likely GHG emissions from Shanghai's transport sector in 2020.

The key parameters for the two scenarios are presented in Tables 2 and 3. They include population,⁵⁴ amount of motorized and non-motorized travel by mode and fuel, fuel consumption characteristics, and average vehicle occupancies.

Table 2

Key Parameters for Scenarios

	2000	2020	
Passengers per vehicle		Low	High
Passenger car	2.5	3.0	2.5
Scooter	1.2	1.3	1.2
Minicar	1.5	1.8	1.5
Bicycle	1.0	1.0	1.0
Bus	27	32	27
Passenger Modal Split by Passenger-Kilometer (Percent)		Low	High
Gasoline cars	14	25	52
Diesel cars	0	5	0
CNG cars	1	3	0
Gasoline minicars	0	1	0
Battery and fuel cell minicars	0	4	0
Two-stroke two-wheelers	12	0	2
Electric two-wheelers	0	6	0
Four-stroke two-wheelers	0	7	5
Diesel bus	20	15	15
Gasoline bus	19	1	6
CNG bus	0	3	2
Fuel cell bus	0	2	0
Rail transit	0	16	12
Walking	7	3	3
Bicycle	27	9	3
Total	100	100	100
Other Parameters		Low	High
Population (millions)	13	16	18
Total passenger travel (ratio)	1*	3.4	4.2

*baseline

Table 3

Greenhouse Gas Emissions for Vehicles and Fuels in Shanghai,
CO₂-equivalent Grams/Vehicle-kilometer

	2000		2020	
	Fuel (km/liter)	GHG (g/vehicle-km)	Fuel (km/liter)	GHG (g/vehicle-km)
Gasoline Motor Scooter (two-stroke)	32.1	130	35.5	99
Gasoline Motor Scooter (four-stroke)	44.9	77	49.7	67
Electric Motor Scooter	N/A	60*	N/A	59*
Gasoline Minicar	24.7	118	28.5	118
Gasoline Car	10.7	343	10.7	343
Diesel Car	15.8	213	15.8	213
CNG Car	N/A	277	N/A	248
Electric Car	N/A	N/A	N/A	244*
Diesel Bus	3.3	944	3.3	986
Gasoline Bus	2.2	1439	2.2	1462
CNG Bus	N/A	1040	N/A	967
Fuel Cell Bus (methanol)	N/A	N/A	N/A	684

*The average generating mix for China used in calculating greenhouse gas emissions for battery electric vehicles and rail transit is as follows: 78 percent coal, 15 percent hydroelectric, 4 percent oil, 2 percent nuclear, and 1 percent natural gas.

Source: See Appendix for sources of fuel consumption estimates and GHG calculations.

B. High Greenhouse Gas Emissions Scenario

This scenario is premised on market forces playing a greater role in the economy and government playing a lesser role. Shanghai follows the path of fast-growing cities in Asia that have relatively high car ownership and GHG emissions for their income levels. These cities include Bangkok and Jakarta, both known for their high levels of air pollution and traffic congestion.

It is assumed that Shanghai and the central government determine that the automotive industry will be a pillar of economic development, as conceived in the 1990s. Consumer choice is allowed to flourish, and a greater share of wealth is created and managed by the private sector.

Following this scenario of expanding private sector initiative and lessening government control, it is postulated that investments in alternative fuels founder, immigration accelerates, and investments in large public infrastructure projects slow, especially for rail transit. The car population increases fourfold, the mid-range forecast of the Shanghai Comprehensive Transportation Planning Institute. Immigration exceeds official forecasts, with the overall population expanding to 18 million (compared to 13 million in 2000 and 16 million in 2020 for the low emissions scenario). Increased immigration puts pressure on the municipal budget.

Though the demand for transport increases greatly and the decentralization plan is well underway, the government is unable to respond in this scenario as it did in the 1990s. Funding for rail transit is suspended after only five of the ten planned lines are built. Those lines that are running are popular, but daily trips by rail are only convenient for a fraction of the population. An increasing share of funds is diverted to buses, which require less capital investment than rail. Bicycle use remains high among the poor. Others walk or use buses. More bicycle lanes are built to serve the high demand and reduce conflicts with vehicles and buses on mixed-use roads.

Not all these changes increase greenhouse gases. Indeed, buses emit only about half the amount of greenhouse gases as rail (on a lifecycle basis). Thus shifting travel to buses is beneficial for climate change.⁵⁵

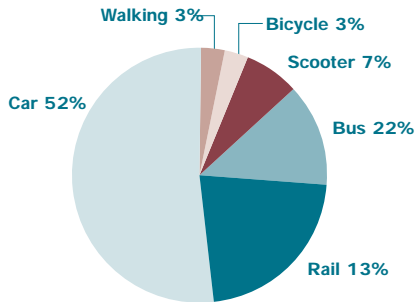
The shift toward personal motor vehicles (motorcycles, scooters, and cars) accelerates for several reasons and has strongly negative GHG implications. With increased income, reduced car prices, and newly available consumer credit, many more people can purchase vehicles. Frustration over poor quality buses and longer commutes to work lead to increased car buying. Work trips lengthen because jobs and housing become more dispersed due to multi-centralization.

The private automobile is a symbol of wealth in Shanghai, and wealthier residents use their cars regularly despite deteriorating traffic conditions. Dirty, inefficient two-stroke scooters and motorcycles remain banned and are replaced by clean four-stroke and electric two-wheelers. These motorized two-wheelers produce about one-third fewer GHG emissions than two-stroke scooters and motorcycles (see Table 4), but their large number and intensive use results in a substantial overall increase in emissions.

The central government pursues its plan to create a strong domestic auto industry with large investments from international automakers. The principal target markets are large Chinese cities such as Shanghai. Shanghai is successful in attracting a disproportionate share of the automaker investments. City officials relax vehicle taxes and other restrictions in response to the growing political clout of the local automotive industry and local motorists.

Figure 6

Mode of Travel in Passenger-kilometers, High Emissions Scenario (2020)



Cars increase their share of total passenger travel from 16 percent in 2000 to 52 percent in 2020, following from the projected quadrupling of the car population. Scooters and motorcycles drop from 12 to 7 percent, bicycles from 27 to 3 percent, walking from 7 to 3 percent, and mass transit (bus and rail combined) from 39 to 35 percent (see Figure 6). These reductions in non-motorized travel are large, but comparable with other major cities. They result from an influx of poor immigrants who cannot afford bicycles, lower population densities, and greater motorization. Emissions per passenger-kilometer almost double and total GHG emissions increase sevenfold.

C. Low Greenhouse Gas Emissions Scenario

In the low emissions scenario, Shanghai follows the path of cities such as Singapore, Tokyo, and Hong Kong. As in Singapore, government plays an active role in restraining vehicle purchases and use.

+ But the challenge is much greater for Shanghai since it is much larger.

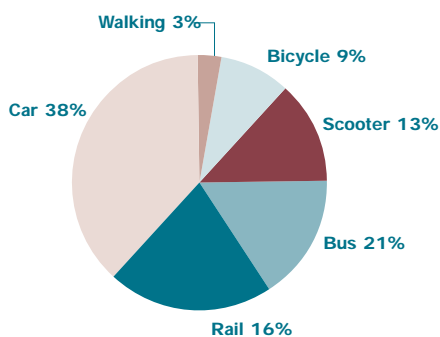
Energy use and GHG emissions are much lower in this scenario, and rail transit plays a major role. Although rail transit is more GHG-intensive than buses, trains provide high quality service at high capacity, an attractive alternative to private vehicle use. The availability of high-quality rail transit slows the shift to personal vehicles, and thereby slows increases in greenhouse gases.

+ Motor vehicle growth management policies, such as limitations on vehicle registrations, remain effective. With the population remaining relatively stable and income growing quickly, public resources are available for transportation improvements. The rail transit system is completed on schedule in 2010, and ridership is high. High-density housing is available near rail lines in satellite cities. Extensive bicycle park-and-ride lots at rail stations encourage daily commuters to use bicycles and public transport. The city invests in improved bicycle lanes and high-tech vertical bicycle parking structures at high-volume stations in dense areas.

Following accession to the WTO, the central government abandons the idea of creating an auto industry founded on conventional cars and technology. Local companies find it difficult to compete directly with automobiles from the international market. Instead, Shanghai encourages local manufacturers to build minicars, also known as city cars, and farm cars for rural areas. Disincentives are imposed on the use of larger vehicles. To provide a release for pent-up vehicle demand, Shanghai also provides seed funding, technical assistance, and parking and purchase incentives for car sharing organizations proliferating around the city.

Minicars become very popular. An increasing number are powered by electricity, although some have small internal combustion engines that burn gasoline and diesel fuel. Some use hybridized combinations of batteries and combustion engines. After 2010, fuel cells are used. Minicars are narrower and approximately half the length of full-sized vehicles, and therefore cause substantially less traffic congestion and consume much less space for parking. The lower volume of bicycle and vehicle traffic on the roads allows the remaining traffic to move faster, including buses. This helps the Shanghai bus system to establish and maintain a strong reputation for reliability and increases ridership. The city continues with its multi-centralization strategy, and satellite cities are served primarily by express bus and rail transit. Those who own city cars are able to drive them from the satellite cities to central Shanghai on roads built exclusively for city cars, motorcycles, and scooters. Because they handle only small, light vehicles, such roads take less space and cost much less to build than conventional roads. Separate but contiguous lanes are built to higher standards at higher cost for express buses and freight trucks.

Figure 7
Mode of Travel in Passenger-kilometers, Low Emissions Scenario (2020)



In this scenario, cars (including minicars) increase their share of travel from 15 to 38 percent between 2000 and 2020; mass transit, motorcycles, and scooters maintain their current share; and walking and bicycling drop considerably (though the absolute amount of travel by walking and bicycling stays roughly constant) (see Figure 7). Pollution, energy use, and greenhouse gases are restrained by using cleaner fuels

and more energy-efficient technologies. Emissions per passenger-kilometer increase only about 10 percent, but the net result of more people and more travel results in a fourfold increase in total GHG emissions.

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+ **Transportation** Scenarios for Shanghai, China

V. Conclusion

Shanghai's current transportation sector generates few greenhouse gas emissions, both in absolute and per capita terms. Shanghai has few vehicles, and only 15,000-50,000 privately-owned cars among a population of 13 million people. The transportation sector accounts for only about 6 percent of its total GHG emissions. The city's plans for its transportation system are being developed in conjunction with other planning objectives, including efforts to lower population density and improve air quality through decentralization of industrial and commercial activities. Although decentralization has been occurring for a decade, Shanghai will change very rapidly in the short to medium term.

Under any plausible scenario, there will be a large increase in GHG emissions from Shanghai's transportation sector. This report describes two scenarios that represent an upper and lower trajectory of these emissions. The scenarios are premised on continued strong economic growth. The difference between these scenarios is a fourfold versus a sevenfold increase in emissions. Many variables influence these projections, including (1) national and local support of the domestic automotive industry; (2) China's imminent accession to the World Trade Organization and the effect on consumer credit and vehicle availability and price; (3) success of the multi-centralization plan; (4) investments in public transit; (5) policies toward motorcycles and scooters; and (6) population growth rates. The vast difference between the two scenarios suggests that there are many opportunities to effect large reductions in greenhouse gases.

Shanghai is already actively pursuing a broad range of transportation policies and investments. These include investments in rail transit and busways, and conventional roads, bridges, and tunnels, many of which support the multi-centralization strategies of Shanghai. Major investments are also being made in "intelligent" transportation technologies for traffic control, and new freight transport terminals and distribution centers on the outskirts of the city (important in helping divert large intercity trucks away from city streets).

Existing efforts appear well organized, and policies and programs seem well-integrated across various levels of city planning. But escalating demand for increased travel and vehicle ownership will create pressure for change. If motorization and future GHG emissions are to be restrained, redoubled commitment to these policies is necessary now. Especially important are commitments to public transportation and restraints on car use.

The heart of these expanded initiatives must be the provision of a high quality array of transportation options to travelers, including enhanced mass transit services for those otherwise inclined to shift to personal vehicles. This strategy would lead to better use of existing infrastructure and less need for infrastructure investment. It would also lead to slower increases in GHG emissions. Below are possible initiatives that Shanghai might pursue that enhance the quality of transportation services, meet the objectives of Shanghai planners, and are climate friendly:

- *Specialized, lower cost infrastructure for smaller vehicles and bicycles.* This would enhance traffic circulation and improve safety for all travelers.
- *Clean and efficient propulsion technology in vehicles.* As outdated technologies are phased out, they are replaced with more efficient, cleaner-burning engines and fuels.
- + • *Information and communication technologies.* These could be used in creative ways to enhance traffic circulation, improve transit services, facilitate shared use and ownership of vehicles, and strengthen inter-modal connections between different transport options.
- *Cars and other vehicles adapted to conditions in Shanghai.* With road and parking spaces at a premium, discouragement of conventional-sized cars in favor of minicars and clean, efficient motorcycles and scooters will help prevent congestion.
- + • *Express (rapid transit) buses.* Dedicated bus lanes and high quality bus service would enhance the attractiveness of bus travel and thereby ease the demand for personal-use vehicles.
- *Dual-mode car systems.* This option is perhaps most revolutionary, but provides the potential for personalized transport that is less expensive and environmentally superior to conventional cars. Small cars with small battery packs (and perhaps fuel cells eventually) would operate on an electrified road and, if coupled with automated control, would allow a much higher road capacity.

While Shanghai is unique in many respects, virtually all of the strategies and policies proposed here are applicable to other cities. To the extent that Shanghai can restrain motorization and GHG emissions by adopting such recommendations, as in the low emissions scenario, Shanghai could serve as a model for other cities in the developing world. However, if vehicle use, energy consumption, and greenhouse gases skyrocket in Shanghai, as in the high emissions scenario, it is a signal that restraint of transport-related GHG emissions will be virtually impossible throughout the developing world.

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Glossary

Busway: One or more lanes dedicated to the use of buses.

Four-stroke engine: Almost all cars and light trucks and some motorized two-wheelers use four-stroke engines. In these engines, fuel and air enters the cylinder, is compressed by the piston, ignited by a spark from the spark plug (the power stroke), and then exhaust gases are pushed out. These engines are generally more expensive than two-stroke engines, but more energy-efficient and cleaner burning.

Gross City Product: The total market value of all the goods and services produced by a city during a specified period.

Load factor: Average number of occupants in a vehicle, sometimes expressed as a fraction of capacity, sometimes as number of people. Also used for freight vehicles, expressed as fraction of capacity or number of tons.

Metro: Short for "metropolitan railway." Passenger rail transit system with dedicated right-of-way that often is partly underground and within a metropolitan area. Some cities use other names. San Francisco uses "BART," New York uses "subway," and London uses "underground."

Minicar: Car designed for urban use. In Japan, defined as a vehicle with engine capacity of 660 cc or less. Also known as "city car."

Modal split: The share of total passenger or freight travel on different kinds of transportation, usually measured as a percent or fraction.

Mopeds: Two-wheelers with engine capacity less than 50 cc. They move at about the same speed as bicycles, but require little or no pedaling. They operate in bicycle lanes and within the flow of bicycle traffic.

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Passenger-kilometer: One passenger moving one kilometer. This is the same as one person-kilometer.

Scooter: Motorized two-wheelers that tend to have less power and speed and smaller wheels than motorcycles. In Shanghai, most motorcycles are so small that scooters and motorcycles are roughly equivalent in size and performance. In this report, scooters include small motorcycles.

Two-stroke engine: These internal combustion engines burn a mixture of gasoline and oil. These engines are used mostly in small, inexpensive scooters and motorcycles. They are generally simpler and less expensive than four-stroke engines, but less energy efficient and more polluting, especially when fuels are not pre-mixed correctly and when inexpensive substitutes are used.

Two-wheelers: Includes bicycles, mopeds, scooters, and motorcycles.

Vehicle-kilometer: One vehicle moving one kilometer.

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Yuan: Chinese currency. 8.28 Yuan = U.S. \$1.

Appendix

Research Approach

This report was a collaboration between researchers at the University of California, Davis and Hongchang Zhou of Tongji University in Shanghai. The report is based on an extensive review of the literature, a series of interviews in December 1999 with experts and leaders in Beijing and Shanghai, further review of reports and other materials identified during interviews, and data analyses conducted by Dr. Zhou and Dr. Mark Deluchi of the Institute of Transportation Studies at the University of California, Davis. The final set of parameters was specified after extensive consultation among the authors and with others. The numeric measures were converted by Dr. Delucchi into quantitative GHG emissions estimates for the two scenarios.

Interviewees

Branstetter, Lee. Assistant Professor, Department of Economics, University of California, Davis.

Chen, Lifan. Professor, Department of Automotive Engineering, Tongji University, Shanghai.

Chen, Changhong. Shanghai Environmental Research Institute, Shanghai Environmental Protection Administration.

He, Kebin. Professor, Department of Environmental Science and Engineering, Tsinghua University, Beijing.

Li, Pei. State Environmental Protection Administration, Head of Mobile Source Pollution, Division of Air Pollution and Noise Control, Beijing.

Lu, Ximing. Senior Engineer and Director. Shanghai City Comprehensive Transport Planning Institute, Shanghai Planning Bureau.

Ma, Lin. Chief Engineer, Urban Transport Center, Ministry of Construction, Beijing.

Rozelle, Scott. Associate Professor, Agricultural and Resource Economics Department, University of California, Davis.

Sun, Lijun, Professor and Chair, Department of Road and Traffic Engineering, Tongji University, Shanghai.

Tang, Dagang. Director, Atmospheric Environment Institute, Chinese Research Academy of Environmental Sciences, Beijing.

Tang, Zongbo. Professor, School of Architecture, Department of Urban Planning, Tsinghua University, Beijing.

Wei, Zhihong. Professor and Deputy Director, Global Climate Change Institute, Tsinghua University, Beijing.

Zhao, Jie. Senior Engineer and Deputy Director, Urban Transport Center, Ministry of Construction, Beijing.

Overview of Lifecycle Energy Use and Emissions Model (LEM)

There are many ways to produce and use energy, and many sources of emissions in an energy-production-and-use pathway. Several kinds of greenhouse gases are also emitted at each source. An evaluation of GHG emissions associated with transportation activities must be broad, detailed, and systematic. It must encompass the full “lifecycle” emissions of a particular technology or policy, and include all of the relevant pollutants and their effects. To this end, Dr. Delucchi has developed a detailed, comprehensive model of lifecycle emissions of urban air pollutants and greenhouse gases from various transportation modes. Many governments and companies use this model. The model was updated and adapted for Shanghai for this report by Dr. Delucchi.

The Lifecycle Energy Use and Emissions Model (LEM) considers motorized two-wheelers, cars, buses, and trucks operating on a range of fuel types and propulsion technologies; bicycles; heavy-rail and light-rail transit; ships; and freight railroads. The LEM estimates energy use, GHG emissions, and urban air pollutants for the transportation modes listed above. The model includes lifecycles for fuels and electricity (end use, fuel dispensing, fuel distribution, fuel production, feedstock transport, and feedstock production), vehicles (materials production, vehicle assembly, operation and maintenance, and indirect support infrastructure), and infrastructure (materials for infrastructure, and construction of infrastructure). Greenhouse gas results mentioned in this report include only emissions associated with fuels and electricity since accurate data are unavailable in China for materials, manufacturing, and construction.

The LEM characterizes emissions of greenhouse gases and criteria pollutants from several sources: fuel combustion, evaporation and leakage of liquid fuels, venting or flaring of gas mixtures, chemical transformations, and changes in the carbon content of solid or biomass. It estimates emissions of CO₂, methane, nitrous oxide, carbon monoxide, oxides of nitrogen, nonmethane organic compounds, sulfur dioxide, particular matter, CFC-12, and HFC-134a. The LEM estimates emissions of each pollutant individually, and also converts the GHG emissions into CO₂-equivalent GHG emissions. To calculate total CO₂-equivalent emissions, the model uses CO₂-equivalency factors (CEFs) that convert mass emissions of all non-CO₂ gases into an equivalent mass amount of CO₂. Delucchi derived these CEFs using a variety of sources and methods, including but not limited to research by others on Global Warming Potentials (GWPs) and Economic Damage Indices (EDIs). GWPs relate different gases to CO₂ in terms of their relative effects on global warming. EDIs relate the gases to CO₂ in terms of their relative warming-induced economic damages. As a sensitivity analysis, the LEM model was also run taking into account only those

gases for which the Intergovernmental Panel on Climate Change has published GWPs relative to CO₂, and using those GWPs instead of the CEFs. This made about a 1-10 percent difference in the GHG emission estimate and did not affect the relative difference between the scenarios.

Travel:

Data specific to China and Shanghai used for this report come from a variety of sources. Liu et al. (1996) report fuel consumption data for light duty gasoline and diesel vehicles; Wang et al. (1996) report on standard buses, articulated buses, and trolley buses (including load factors and vehicle life-times); Qiu et al. (1996) report on freight trucks; and this report's co-author, Zhou, collected unpublished data from various researchers in China, especially for motorized two-wheelers. Delucchi and the other co-authors of this report used other data, unpublished information solicited from Chinese experts, and their own professional judgment to make small adjustments in these data.

Electricity:

The U.S. Energy Information Administration's (EIA's) *International Energy Outlook* (1999) reports fuel-use shares for electricity generation in 1996 and 2020. The EIA (1999) indicates that Chinese coal-fired power plants emit at least three times as much sulfur oxides per kWh as do coal-fired plants in the United States. In its *Country Analysis Brief for China*, the EIA (2000) notes that Chinese coal has a high sulfur content; it is assumed here to be 50 percent higher than in the United States. Chen (1996) states that although coal-fired power plants in China are becoming cleaner and more efficient, they still are dirtier and less efficient than coal plants in developed countries. Qiu et al. (1996) report that Chinese coal-fired plants were about 29 percent efficient in 1994, and that the electricity distribution system was 91.3 percent efficient. These energy efficiency figures are accepted, but assumed to increase 0.4 percent per year, reaching 32 percent (the current level in the United States) in 2020.

Oil and Gas:

The U.S. EIA's *International Energy Outlook* (1999) reports oil imports and total oil consumption for China in 1996 and 2020. This publication projects that oil imports to China from the Persian Gulf will grow from almost 20 percent of total oil consumption in 1990 to over 50 percent in 2020. Delucchi represents this information by assuming that 15 percent of total oil consumption comes from the Persian Gulf in 1970, and that the share increases by 2.5 percent per year (in relative terms, not absolute percentage points) up to a maximum of 70 percent. However, oil imports can vary dramatically from year to year due to changes in government policy or the world oil market. The U.S. EIA (1996) states that Chinese refineries typically generate their own electricity, mainly from coal, the authors presume. Given this information, Delucchi assumes that refineries in Asian oil-producing countries buy less electricity but more coal than refineries in other major oil-producing regions. Because it takes roughly 3 energy units of bought coal to produce the equivalent of 1 energy unit of bought electricity, Asian refineries in this accounting have slightly higher total "internal" energy requirements than do refineries that buy electricity rather than generating it internally.

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The 1997 version of the model is documented in several reports, shown below. Complete, up-to-date working documentation is available from the author (note Dr. Delucchi changed the spelling of his name from DeLuchi in the mid-1990s.).

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2. Stiglitz, Joseph. 1997. "The Future of China." Speech at World Bank-International Monetary Fund Annual Meeting, Hong Kong SAR, China, September 22.
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4. The major greenhouse gases emitted by the transport sector are CO₂, nitrous oxide, and methane. Most analysts focus on CO₂ because it is emitted in large quantities and these emissions are relatively easy to measure. This is especially true in the transport sector: CO₂ is by far the most important greenhouse gas emitted when petroleum fuels are burned, and petroleum fuels account for over 95 percent of the fuel burned in the world's vehicles. Unlike many other gases produced from the consumption of fossil fuels, CO₂ cannot easily be filtered from the exhaust. Therefore, CO₂ emissions are almost directly proportional to the quantity of petroleum fuel consumed.
5. X. Wang. 1998. "Greenhouse gas emission in Shanghai," *Fuel and Energy Abstracts* 39(1), January, p. 61.
6. International Energy Agency. 2000. *CO₂ Emissions from Fuel Combustion: 1971-1998*. Paris, pp. II.82-II.84.
7. There is considerable disagreement about Shanghai's population. The official statistics list 13 million registered residents of the Shanghai Metropolitan area (including some rural areas), but there are an estimated 3 million more people who enter Shanghai for short business stays and other purposes.
8. Wu, Weiping. 1999. "City profile: Shanghai," *Cities*, 16(3), p. 210; Mei, Anxin, Jianping Wu, and Luxi Zhi. "Shanghai's Land Use," In *The Dragon's Head: Shanghai, China's Emerging Megacity*. Foster, Harold D., David Chuenyan Lai, Naisheng Zhou (eds.), Western Geographical Press: 1998, p. 126; Kenworthy, Jeffrey R. and Felix B. Laube. *An International Sourcebook of Automobile Dependence in Cities 1960-1990*, University Press of Colorado: Boulder, p. 249.
9. Mei et al., 1998. p. 119.
10. Kenworthy and Laube, 1999, p. 393.
11. Lu, Ximing, 1999. Personal Interview. Shanghai City Comprehensive Transportation Planning Institute. December; Mei et al., 1998, p. 128; Wu, 1999, p. 210, Figure 2.
12. Wu, 1999, p. 209.
13. Ibid., p. 207.
14. *Statistical Yearbook of Shanghai*, 1998. China Statistical Publishing House, Beijing.
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18. See, for instance, Stares, Stephen and Zhi Liu (eds.). 1995. *China's Urban Transport Development Strategy*. World Bank Discussion Paper No. 352, p. 489 and Chang, D. Tilly. 1999/2000. "A new era for public transport development in China," In The Woodrow Wilson Center's *China Environment Series*, Issue 3, Washington, DC, pp. 22-27.

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20. Official sources from 1998 indicate 10,000 privately-owned vehicles. See *Shanghai City Transportation Study 1997*, Shanghai City Comprehensive Transportation Planning Institute, 1998, p.5; and Da Rao. 1999. "Analysis on private car purchasing in Beijing and Shanghai." *China Autos*. October. Informally, city officials indicate the number to be closer to 20,000. But the car manufacturing companies in Shanghai indicate that their employees own about 10,000 personal vehicles. Executives at the Shanghai Automotive Industry Corporation, the Chinese holding company for joint ventures with VW, GM, and others, indicate that an additional 30,000 or so employees of major Shanghai companies own their own vehicles but have registered their vehicles through their employers — and thus the City does not record those 30,000 or so as privately owned.

21. Shanghai City Comprehensive Transportation Planning Institute. 1997. *Metropolitan Transport Comparative Study—Shanghai Report for United Nations Centre for Regional Development (UNCRD)*, p. 5.

22. Written briefing provided by Shanghai government planners for visiting National Academy of Science committee, May 16, 2001, and affirmed by senior planners. Also see Ying, Dinghua. 1998. "Shanghai's Land Use." In *The Dragon's Head*, p. 155.

23. Modal shares measured in terms of passenger-kilometers are calculated using estimates of typical travel distances by mode, average loads on each mode, and number of trips by mode. To estimate passenger-kilometers, multiply the number of passengers by the distance traveled. For example, ten passenger-kilometers could equal one passenger traveling ten miles or ten passengers traveling one mile.

24. Not all sources agree on transportation statistics presented here. For instance, Shanghai government data indicate somewhat lower non-motorized shares than World Bank sources (see Chang, D. Tilly. 1999/2000, p. 24). These data uncertainties do not, however, undermine the central observation that non-motorized travel in Shanghai continues to be unusually high, facilitated by the city's high population density and mixed land uses. Mixed land use, meaning combined rather than separate areas for industrial, commercial, and residential use, tends to result in fewer long-distance trips, especially in cities, since shopping, work, and school destinations can be more clustered.

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27. A mandate in Taiwan requiring a growing proportion of zero-emission (battery-powered) two-wheelers suggests that this new technology may become more competitive in the near future.

28. Shanghai City Comprehensive Transportation Planning Institute, *Shanghai Transportation Report*, 1997 and 1998. From 1991 to 1998, total investment for urban infrastructure was 261.7 billion Chinese Yuan, accounting for 14.6% of Shanghai's gross city product for that period. Of the 261.7 billion Yuan, 48.27 billion was reportedly allocated for urban road transport infrastructure construction, representing 2.7% of Shanghai's gross city product, but other local government reports indicate the percentage for roads to be as much as twice as great.

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45. Logan, Jeffrey, 2000. "Energy and Emissions for the 21st Century Environment," *China Clippings 8*, The Energy Foundation, San Francisco, California, December, pp. 30-31.

46. "Environmentally Sound Transport Tools for the Next Century," *Shanghai Evening News*, February 10, 2000.

47. Shanghai Highway Administration, "Shanghai metropolitan highway network planning, 1999-2010." June, 1999, pp. 5-11.

48. Wu, Yong, and Xiaojiang Li. 1999. "Improve urban transport, protect urban environment — sustainable development for Chinese urban transportation." In *China Urban Transportation for the 21st Century*. China Construction Publishing House, Beijing, p. 49.

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50. Stares, and Liu 1995. p. 82.

51. Wang, Bin. 1999. "City to initiate one-card transit." *Shanghai Daily*. December 28.

52. "Carsharing 2000: Sustainable Transport's Missing Link," special issue of *The Journal of World Transport Policy and Practice* 5(3), September; and Shaheen, Susan, Daniel Sperling, and Conrad Wagner. 1998. "Car Sharing in Europe and North America: Past and Future." *Transportation Quarterly* 52(3), pp. 35-52. Also, see Gakenheimer, Ralph, and Daniel DeLisi, "Urban China Adjusting to Motorization: A Place for Car Sharing?" The Cooperative Mobility Program, MIT, May 2000, p.36.

53. Conductive charging involves direct contact with an electric wire or rail (as with trolley buses and electrified trains that have overhead catenaries or third rails). In inductive charging, the charge is induced through a gap of several centimeters between a plate on the vehicle and wires embedded in the pavement.

54. The official long-term projection is for Shanghai's official population to gradually increase from 13 to 16 million (Xia and Lu, 1999, p. 22). But another future is plausible. Shanghai's population has increased slowly in recent years as the result of two major policies. The first is the national family planning policy that provides strong incentives for single child families. The second policy is the local resident registration system described earlier that restricts domestic migration. In the future, as the market economy expands and the population of Shanghai ages, it may become increasingly difficult to keep poor rural residents from moving to richer cities like Shanghai. Indeed, Shanghai already houses a "floating population" numbering in the millions. Shanghai will become an increasingly strong magnet for immigration, especially for young workers from rural areas.

55. In the United States, rail transit on average uses somewhat less operating energy than buses. But on a full lifecycle basis, considering the large amount of energy used for building and maintaining the rail guideways and the many maintenance services and vehicles required, the opposite tends to be true. In Shanghai, several factors also favor buses. Shanghai buses are relatively more energy-efficient than U.S. buses because they do not have air conditioning, are built with lighter construction, and are more intensively used. Rail is built according to more energy-intensive international standards and operates largely on electricity from coal, which is carbon-intensive.

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This report looks at the greenhouse gas emissions from the transportation sector in Shanghai, China, to identify policies and technologies to simultaneously reduce emissions growth while improving air quality, reducing congestion, improving safety and enhancing transportation services. The Pew Center on Global Climate Change was established by the Pew Charitable Trusts to bring a new cooperative approach and critical scientific, economic, and technological expertise to the global climate change debate. We intend to inform this debate through wide-ranging analyses that will add new facts and perspectives in four areas: policy (domestic and international), economics, environment, and solutions.



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