ANL/ES/CP-102554

Projections of Motor Vehicle Growth, Fuel Consumption and CO_2 Emissions for the Next Thirty Years in China

(Paper Number: 01-0305)

Dongquan He and Michael Wang

Center for Transportation Research
Argonne National Laboratory

To be Submitted to the 2001 Annual Meeting of Transportation Research Board

July 31, 2000

DISCLAIMER

Abstract

Since the early 1990s, China's motor vehicles have entered a period of fast growth resultant from the rapid economic expansion. As the largest developing country, the fast growth of China's motor vehicles will have tremendous effects on the world's automotive and fuel market and on global CO_2 emissions. In this study, we projected Chinese vehicle stocks for different vehicle types on the provincial level. First, we reviewed the historical data of China's vehicle growth in the past 10 years and the correlationships between vehicle growth and economic growth in China. Second, we investigated historical vehicle growth trends in selected developed countries over the past 50 or so years. Third, we established a vehicle growth scenario based on the historical trends in several developed nations. Fourth, we estimated fuel economy, annual mileage and other vehicle usage parameters for Chinese vehicles. Finally, we projected vehicle stocks and estimated motor fuel use and CO_2 emissions in each Chinese province from 2000 to 2030.

Our results show that China will continue the rapid vehicle growth, increase gasoline and diesel consumption and increased CO_2 emissions in the next 30 years. We estimated that by year 2030, Chinese motor vehicle fuel consumption and CO_2 emissions could reach the current U.S. levels.

Introduction

With the rapid economic growth in the last 15 years, China has experienced a fast growth in motor vehicle population. Chinese vehicle stocks were almost quadrupled from 1985 to 1995, with an average annual growth rate of 14.5% over the period (CEPA, 1997). This fast growth causes China to begin to import oil from other countries and cause serious urban air pollution problems.

Though the importance of Chinese vehicle growth has been emphasized in the past few years (for example, see Lee et al., 1999), the magnitude of the impacts is less understood. Projections of Chinese vehicle growth often omit the fact that there are large differences in economic developments among different regions in China. In our study, using state statistics on economic and population growth, we established a scenario of Chinese motor vehicle growth. We estimated vehicle growth, energy use, and CO_2 emissions at provincial level and then aggregated provincial results together.

Methodologies

Vehicle population growth will be different among various vehicle types. In our study, we separated Chinese vehicle stocks into six groups: passenger cars, passenger vans, buses, light-duty trucks (LDT), heavy-duty trucks (HDT), and motorcycles and projected growth for each group.

Projection of Vehicle Populations by Vehicle Type and Province

In projecting vehicle growth, we considered (1) the historical trend of Chinese vehicle population growth in relation to population and economic growth, and (2) historical vehicle growth trends in several developed countries in relation to population. We used vehicle ownership in number of vehicles per 1,000 persons as the primary parameter to determine vehicle growth.

Historical Chinese Vehicle Population Growth

Analysis of National Data. We obtained annual vehicle stocks from China Statistics Yearbook (1990-1998) (Table 1). However, data obtained in this way is only classified as passenger vehicles and trucks. To separate vehicles into smaller groups for our study purpose, we used data from several other sources (see Table 2). Most of the data in Table 2 are based on the number of registered in-use vehicles in China.

Table 1. Chinese Vehicle Stocks (Thousands) [a]

	1990	1992	1995	1997
Total Vehicles	**5,514**	**6,917**	**10,400**	**12,191**
Passenger Vehicles [b]	1,622	2,262	4,179	5,806
Trucks [c]	3,685	4,415	5,854	6,012
Special Vehicles [d]	207	241	367	373

[a] From China Statistics Yearbook, 1990-1998

[b] Include passenger cars, passenger vans, and buses.

[c] Include light duty trucks and heavy duty trucks.

[d] Include special-purpose vehicles such as fire trucks and off-road trucks (e.g., mining operation vehicles and construction vehicles).

Table 2. Chinese Vehicle Stocks by Vehicle Group (Thousand)

		1990	**1992**	**1994**	**1995**	**1997**
Reference 1	Cars	619	939		1,795	2,384
Reference 2	Cars and vans	1,289				
	LDTs	1,186				
	HDGTs	2,200				
	HDDTs	838				
	MCs	4,213				
Reference 3	Cars		939	1,611		
	Vans		988	1,500		
	LDTs		1,699	2,504		
	Buses		144	201		
	HDTs		3,244	3,833		
Reference 4	Cars				1,795	
	Vans				1,944	
	LDTs				2,499	
	HDBs				440	
	HDTs				3,187	
	Others				535	

Reference 1: China Ministry of Mechanical Industry (MMI, 1998).
Reference 2: Song, et al. (1994).
Reference 3: MMI (1996).
Reference 4: Fu, et al. (1999).
HDGT— heavy-duty gasoline trucks; HDDT – heavy-duty diesel trucks;
HDB – heavy-duty buses; and MC – motorcycles.

Using data in Tables 1 and 2, we developed estimates of vehicle stocks by vehicle type for 1990 and 1995 (Table 3). The results in Table 3 are our basis for projecting future vehicle growth.

Table 3. Vehicle Stocks by Vehicle Type in 1990 and 1995 (in thousand)

		1990		1995	
		Number	**Share [a]**	**Number**	**Share [a]**
Passenger Vehicles	Cars	619.0	38.2%	1,795.0	43.0%
	Vans	670.0	41.3%	1,944.0	46.5%
	Buses	332.9[b]	20.5%	440.0	10.5%
	Subtotal	**1621.9**	**100.0%**	**4,179.0**	**100.0%**
Trucks	LDTs	1341.2[c]	34.5%	2,900.0	44.0%
	HDTs	2550.5	65.5%	3,321.0	56.0%
	Subtotal	**3891.7**	**100.0%**	**6,221.0**	**100.0%**
Motorcycles		4,213		13,719	
Total		**9,727**		**24,119**	

[a] Shares are for each subcategory. That is, shares by cars, vans, and buses are for the passenger vehicle group; and shares by LDTs and HDTs are for the truck group.
[b] Stock for buses was calculated as the difference between total passenger vehicles (see Table 1) and the total passenger car and vans (estimated by Song, 1994, see Table 2).
c Stock for light duty vehicles was calculated as the sum of light duty vehicles (estimated by Song, 1994, Table2) and the part of the special used vehicles (we assumed 75% of special used vehicles was light duty vehicle).

Disaggregation of National Data to the Provincial Level. Province-specific data is provided in China Statistics Yearbook, but at the two aggregate vehicle groups – passenger vehicles and trucks. We need to disaggregate the two vehicle groups into the six subgroups. We took the following step to accomplish this. Because of the difference in economic state and future development among provinces, we could not apply a national growth rate to each individual province to predict provincial vehicle stocks, especially for passenger vehicles. To better project provincial vehicle growth and then total national vehicle growth, we divided the 30 provinces in China into three regions according to geography and economy. We assumed that the provinces within a same region would have similar economic and vehicle population growth rates, as well as a similar distribution of vehicle types. Table 4 lists the three regions we defined.

In 1999, researchers from Shanghai (Wang, 1999) conducted a study on the prospect of China's passenger car market. The study estimated that in 1990, the share of total passenger cars was 61.0% by the eastern region, 28.1% by the central region, and 10.9% by the western region. In 1995, the share was 60.2%, 28.9%, and 10.9% by the three regions, respectively. Using this data, we calculated passenger car stocks for each region. Stocks for passenger vans and buses were calculated as the difference between the number of passenger vehicles (which are presented in China Statistics Yearbook) and the number of passenger cars estimated here. Moreover, we assumed the split of passenger van and passenger buses for each region identical to the national average (which is presented in Table3). No data was available for the distribution of trucks among the three regions. We used the national average splits for each region. Our estimated shares of each vehicle type in each of the three regions are listed in Table 5. These shares were applied to each individual province within a region to disaggrate passenger vehicles and trucks into the six categories listed in Table 3.

Table 4. Three Regions Defined in Our Study

Region	Provinces Included
Eastern More Developed Region	Beijing, Tianjin, Shanghai, Hebei, Liaoning, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong, Hainan
Central Developing Region	Heilongjiang, Jilin, Shanxi, Henan, Hubei, Hunan, Sha'anxi, Sichuan, Jiangxi, Anhui
Western Less Developed Region	Neimenggu, Tibet, Xinjiang, Ningxia, Guangxi, Guizhou, Yunnan, Qinghai, Gansu

Table 5. Share of Vehicle Types in Three Chinese Regions

		1990			**1995**		
		Eastern	**Central**	**Western**	**Eastern**	**Central**	**Western**
Passenger vehicles	Cars	45.2%	31.4%	29.0%	46.6%	40.0%	34.6%
	Vans	36.6%	45.8%	47.4%	43.5%	48.9%	53.3%
	Buses	18.2%	22.8%	23.6%	9.8%	11.1%	12.1%
	Subtotal	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Trucks	LDTs	34.5%	34.5%	34.5%	44.0%	44.0%	44.0%
	HDTs	65.5%	65.5%	65.5%	56.0%	56.0%	56.0%
	Subtotal	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Relationship between Economic Growth and Vehicle Population Growth. To project vehicle population growth from 1995 to 2000, we developed the relationship between economic growth and vehicle population growth based on data from 1990 to 1995. In particular, we developed two estimates – per-capita GDP, which was obtained by dividing total GDP by human population for a given region, and vehicle stock per 1000 persons, which was calculated by dividing the total vehicle stocks by the human population for the given region.

Then, we calculated the annual average growth rates for per-capita GDP and vehicle stock per 1000 persons with the following equation that we developed. In estimating GDP growth rate, we considered an annual average inflation rate of 10% during the period from 1990 to 1995.

$$AGR = \left(\frac{V_{95}}{V_{90}}\right)^{1/5} - 1 \qquad (1)$$

Where,

AGR is the annual average growth rate for per-capita GDP and per 1000-persons vehicle stock,

V_{95} and V_{90} are the value of per-capita GDP or per-1000-person vehicle stock in 1995 and 1990.

The estimated GDP and vehicle stock growth rates are listed in Table 6. The annual GDP growth rate we calculated is 10.5% between 1990 and 1995, which is close to the annual rate of 10.3% estimated by World Bank (World Bank, 2000). As the table shows, economic growth varies significantly among the three regions in China. The growth in vehicle stocks was dramatic in China between 1990 and 1995. But growth rate varied significantly among vehicle types. Light-duty vehicles, including passenger cars, passenger vans and light-duty trucks showed large growth rates. On the other hand, heavy-duty vehicles, including buses and heavy-duty trucks grew slowly.

We then developed the elasticity of vehicle population growth and economic growth (i.e., the ratio of per-capita vehicle growth rate to per-capita GDP growth rate). As the table shows, elasticity for passenger cars is 1.98 for the eastern region, 1.77 for the central region, and 2.12 for the western region. The high value for the western region may be attributable to the low population in the region.

Table 6. China's Per-Capita GDP and Vehicle Ownership Growth Rates and Their Elasticity Between 1990 and1995

	Per-Capita Annual GDP Growth Rate	Annual Growth Rate of Per-Capita Vehicle Stocks						
		All Vehicles	Cars	Vans	Buses	LDTs	HDTs	MCs
Easten	11.2%	15.3%	22.2%	25.7%	7.4%	17.0%	8.6%	34.2%
Central	10.3%	8.7%	18.1%	21.5%	3.8%	9.6%	1.3%	10.5%
Westen	8.2%	9.9%	17.3%	20.7%	3.1%	11.4%	3.7%	14.1%
National	10.5%	12.2%	20.1%	23.5%	5.6%	13.5%	5.2%	25.1%
		Elasticity between GDP Growth and Vehicle Growth[a]						
Easten		1.36	1.98	2.29	0.66	1.51	0.76	3.04
Central		0.84	1.77	2.09	0.37	0.94	0.12	1.03
Westen		1.21	2.12	2.53	0.38	1.39	0.45	1.72
National		1.15	1.91	2.24	0.53	1.28	0.49	2.38

[a] Elasticity is calculated as the ratio of per-capita vehicle stock growth rate to per-capita GDP growth rate.

Table 6 presents vehicle ownership elasticities for vehicle types between 1990 and 1995. To project vehicle growth from 1995 to 2000 with elasticity, we increased the historical elasticity by 0.5 for cars and by 0.2 for vans, but decreased the elasticity by 0.1 for buses, by 0.3 for light duty trucks and by 0.2 for heavy-duty trucks. Our adjustments here reflect the trend that China's vehicle fleet are shifting from truck dominated fleets to passenger vehicle dominated fleets. Since both economic growth and vehicle stock growth went through fast, unsustainable growth between 1990 and 1995, we could not apply the elasticity values for a long-term projection. Instead, we investigated the historical trends of vehicle stock growth rates in several developed countries and used these trends to project vehicle growth between 2000 and 2030.

Investigation of Vehicle Stock Growth Trend in Developed Countries

Figures 1 and 2 depict historical vehicle stock growth trend in developed countries by vehicle type. As the figures show, Chinese vehicle ownership per 1000 persons is far lower than that in developed countries. Thus, there is a large potential for vehicle population growth in China.

The growth in passenger cars and vans has experienced similar trends as the five developed countries presented in Figure 1. All of the five countries have experienced a fast growth period of 30-40 years, which began in the 1950s for the U.S., Canada, the United Kingdom, and France, and in the 1960s for Japan. After the period, growth rates leveled off. Note that there are decreases in cars and vans per 1000 persons in early 1990s in the U.S. and Canada. This is probably due to reclassification of some passenger cars and vans to light-duty trucks during that period. For countries with abundant land and low population densities (the U.S. And Canada), vehicle ownership per 1000 persons is about 400-500. For countries with scarce land and high population densities (Japan, France, and the U.K.), vehicle ownership for per 1000 persons is about 300-400.

As for buses and trucks, the U.S. has experienced large growth, while growth in other four developed countries has been small and leveled off since the early 1990s.
From the figures, we observe that the growth pattern of passenger cars and vans in China in 1990s looks similar to that in Japan between 1950 and1960. In our study, we assumed that the growth in China's passenger cars and vans would follow the Japanese growth trend by lagging about 30-40 years. As for growth in truck population, since China's policy will mostly likely promote light-duty vehicle growth, especially light-duty passenger vehicles, we assumed that the growth in buses and trucks in China would not follow the trend in Japan. Instead, we assumed the Chinese growth would follow the more gentle growth as experienced in France.

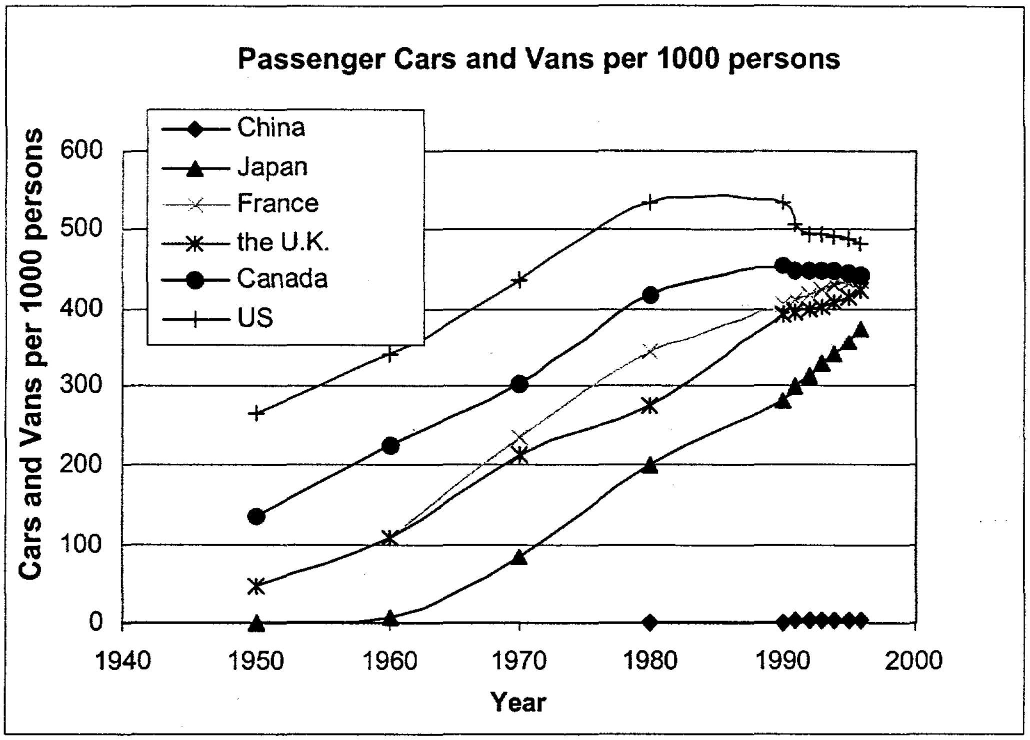


Figure 1. Growth in Passenger Cars and Vans in Five Developed Countries and in China
Sources (Davis, 1999, U.S. Bureau of Census, 2000)

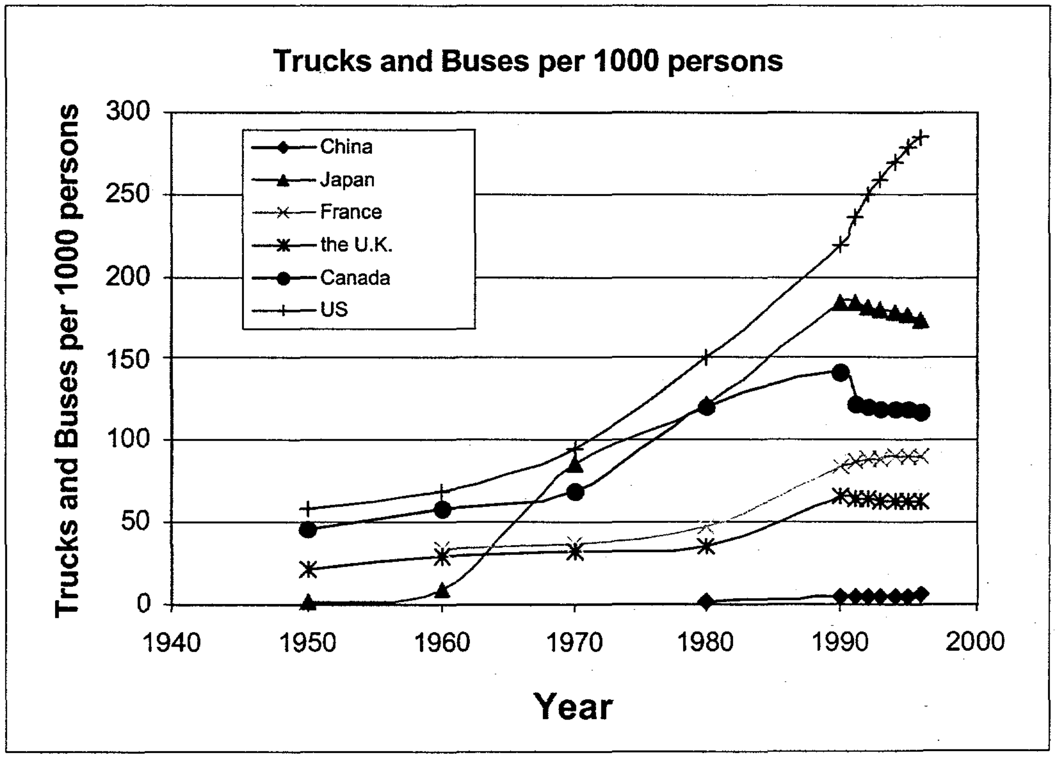


Figure 2. Growth in Trucks and Buses in Five Developed Countries and in China
Sources (Davis, 1999, U.S. Bureau of Census, 2000)

Projection of Chinese Vehicle Stocks by Vehicle Type at the Provincial Level

We estimated vehicle population growth for each province by vehicle type from 2000 to 2030 with the methods mentioned in the above section. In particular, we started with our estimated vehicle population for each province in 1995 and projected the vehicle population to 2000 with elasticities as estimated in Table 6. And then, we projected annual human population growth in each province from 2000 to 2030. We then applied the vehicle ownership growth in Japan and France to each province with a starting point on the Japanese and French growth curves for a given province, depending on vehicle population per 1000 persons in 2000 in that province. We used predicted economic growth in each province to crosscheck our projections from growth rates of human population and vehicle ownership per 1000 persons. If large discrepancies between economic growth and vehicle growth occur relative to historical data, we adjusted our predicted per-1000-person vehicle ownership to make our overall projections more reasonable.

Besides on-road motor vehicles, we projected growth in motorcycles and agriculture vehicles in our study. Although motorcycles experienced rapid growth in 1990s, concern about noise, air pollution, and safety problems associated with motorcycles has created pressures for policy makers to constrain future growth. We assumed that motorcycle stocks would stay about at the current level throughout the projection period. As for agriculture usage vehicles, we separated them into three categories – large/medium tractors, small tractors, and agricultural trucks. We assumed the growth rate of agricultural vehicles to be the same as the predicted agricultural economic growth rate in China, which will be probably about 2% per year for the next 30 years.

Calculation of Fuel Consumption and CO_2 Emissions of Chinese Motor Vehicles

We employed the following equations to calculate fuel consumption by motor vehicles.

$$FC_g = \sum_{i,j} V_{i,j} \times M_i \times F_{g,i} \times D_g \times x_{g,i} \qquad (2)$$

$$FC_d = \sum_{i,j} V_{i,j} \times M_i \times F_{d,i} \times D_d \times (1 - x_{g,i}) \qquad (3)$$

Where, FC_g is gasoline consumption (in metric tons/year)
FC_d is diesel consumption (in metric tons/year)
$V_{i,j}$ is type i vehicle population in province j
M_i is annual vehicle mileage traveled by vehicle type i (in 100 km)
$F_{g,i}$ is fuel consumption of gasoline vehicle type i (liters/100km)
$F_{d,}i$ is fuel consumption of diesel vehicle type i (liters/100km)
D_g is density of gasoline (tons/liter)
D_d is density of diesel (tons/liter)
$x_{g,i}$ is gasoline consumption share of vehicle type i

CO_2 emissions from motor vehicles were calculated with the following equation:

$$EM_{CO2} = (FC_g \times C_g + FC_c \times C_d) / F_c \qquad (4)$$

Where, EM_{CO2} is CO_2 emissions in tons/year

C_g is carbon content of gasoline

C_d is carbon content of diesel fuel

F_c is carbon ratio of CO_2 (0.27)

FC_g and FC_d are defined in Equations 2 and 3.

Splits Between Gasoline and Diesel Consumption by Vehicle Type

Two major fuels used for Chinese motor vehicles are gasoline and diesel. The number of alternative fuel vehicles in China is less than 100,000, less than 1% of total vehicle population. These vehicles are primarily full-size buses and mini-buses. The growth in alternative fuel vehicles in the future will likely be small. We did not include potential contributions of Chinese alternative fuel vehicles. Based on historical data, we estimated the percentage of gasoline consumption out of total consumption of gasoline and diesel (Table 7). Currently, there are no policy initiatives to encourage a shift from gasoline to diesel fuel for light-duty vehicles, we assumed a very moderate increase of diesel fuel use for light duty vehicles. On the other hand, there is a large percentage of gasoline consumption by buses and heavy-duty trucks in China now. Considering diesel vehicles' efficiency advantage, we assumed that gasoline use by buses and heavy-duty trucks would be completely replaced by diesel fuel use in 2030. This is based on Chinese government policies and experiences in developed countries.

Table 7. Predicted Gasoline Consumption Percentages by Vehicle Type

	1990 [a]	**1995** [b]	**2000**	**2010**	**2020**	**2030**
Passenger cars	100%	92%	90%	90%	90%	90%
Passenger vans	100%	90%	90%	85%	80%	75%
Light-duty trucks	100%	90%	90%	85%	80%	75%
Buses	80%	75%	60%	40%	20%	0%
Heavy-duty trucks	72%	60%	60%	40%	20%	0%

[a] From Song, et al. (1994).

[b] From Fu et al. (1999).

Vehicle Mileage Traveled

Table 8 lists annual vehicle mileage traveled (VMT) in China, from two sources. Study by He was for the Beijing metropolitan area and took into account a large number of taxi cabs (nearly 30% of the passenger car fleet) and thus tended to give higher mileage for passenger vehicles. We assumed annual VMT closer to Data from Song. Our projected future annual VMT took into account annual per-vehicle VMT in developed countries.

Table 8. Vehicle Mileage Traveled by Chinese Motor Vehicles (km/yr.)

	Song (1994)	He (1999)	This Study Current	2000	2010	2020	2030
Cars	15,000	37,400	20,000	15,000	10,000	10,000	10,000
Vans	15,000	28,000	21,500	15,000	10,000	10,000	10,000
LTDs	30,000	17,500	20,000	20,000	20,000	20,000	20,000
Buses	30,000	23,900	30,000	30,000	30,000	30,000	30,000
HDTs	30,000	19,700	30,000	32,000	35,000	37,000	40,000
MCs	15,000	10,000	12,500	10,000	10,000	10,000	10,000

Vehicle Fuel Consumption Rates

In predicting vehicle fuel consumption rates in liters/100km, we took into account three factors: the current fuel consumption rates, potential improvements in vehicle fuel consumption based on experiences in other countries, and changes in vehicle sizes over time. Our predicted fuel consumption rates are listed in Table 9. After increases in vehicle fuel economy from 1990 to 2020, we are not certain if fuel economy will continue to improve after 2020, especially considering the experience in North America and Europe in the last 10 years and a potential shift to large-size vehicles in China. We simply assumed fuel consumption rates to be kept steady from 2020 to 2030. As for agriculture vehicles, we assumed the fuel economy of large/medium tractors and agriculture trucks the same as that of heavy-duty diesel trucks, and fuel economy of small tractors the same as that of light duty diesel trucks.

Table 9. Fuel Consumption Rates of Chinese Motor Vehicles (liters/100km)

	Song (1994)	He (1999)	This Study Current	2000	2005	2010	2015	2020	2025	2030
Cars	13.0	8.5	10.0	9.5	9.0	8.0	7.5	7.0	7.0	7.0
Vans	13.0	13.6	13.0	12.0	11.0	10.5	10.0	10.0	10.0	10.0
LDTs	15.5	15.6	15.6	15.0	14.5	14.0	13.6	13.6	13.6	13.6
Gasoline Buses	28.0	22.4	28.0	27.0	26.0	25.0	25.0	25.0	25.0	25.0
Diesel Buses	23.0		23.0	23.0	22.0	21.0	20.0	20.0	20.0	20.0
HD Gasoline Trucks	28.0	24.5	26.0	30.0	29.0	28.0	28.0	28.0	28.0	28.0
HD Diesel Trucks	23.0		23.0	29.0	31.0	33.0	35.0	37.0	37.0	37.0
MCs	3.5	4.3	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9

Results and Discussions

Projected Vehicle Population

Figure 3 presents annual vehicle stocks of various vehicle types. Note that we do not present projections of agricultural vehicle stocks. As the figure shows, from 1995 to 2030, we projected that total vehicle population (excluding agricultural vehicles) will increase from about

24 million in 1995 to 534 million in 2030, an increase of 22 times over the period with an average annual growth rate of about 9.3%. Among the six vehicle types, passenger cars and vans will experience the greatest growth; passenger car and van population will be increased from 3.7 million in 1995 to 481.7 million in 2030 (an average annual growth rate of 14.9%). In 1995, passenger cars and vans in China accounted for 35.9% of total vehicles (excluding motorcycles), whereas in 2030, the share will reach 90%. This large increase reflects the Chinese government policy of promoting family car ownership and a result of economic development. This shift also corresponds to the historical trend of vehicle composition changes in developed countries.

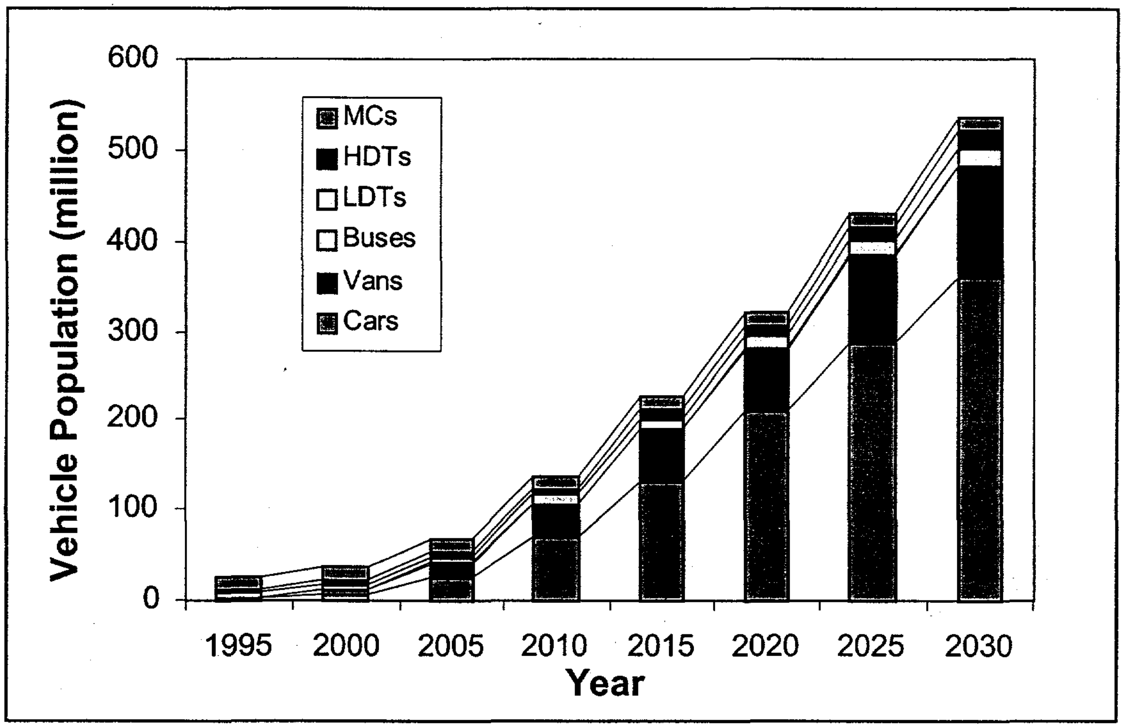


Figure 3. Projection of Annual Vehicle Population in China (in million)

To put our total vehicle projections into perspective with economic and population growth, we present vehicles per 1000 persons in relation to economic growth in Table 10. In 1990s, the elasticity of the growth rate for per-1000-person vehicles with economic growth rate was 1.4 for all vehicles and 2.6 for cars. Based on the experience in developed countries, Wang (1999) maintained that when per-capita annual income is above $2000, vehicle growth elasticity could reach above 3. Table 10 shows that China will reach the elasticity peak between 2000 and 2015 for passenger cars. Vehicle growth rates will then be decelerated because of already large stock base and the limitations of land and resources. For comparison, Table 11 lists per-capita GDP growth rates and their relationship with vehicle stocks growth.

Table 10. Projected Vehicles per 1000 Persons and Elasticity of Vehicle Growth Rate to Economic Growth Rate

		Cars	Vans	Buses	LDTs	HDTs	All Vehicles
1995	Vehicles/1000 Persons	1.5	1.6	0.4	2.4	2.8	8.6
2000	Vehicles/1000 Persons	4.7	4.7	0.4	3.7	3.2	16.7
	Annual Growth Rate (%)	25.8	23.8	4.0	9.4	3.1	14.2
	Elasticity to Economic Growth Rate	2.6	2.4	0.4	0.9	0.3	1.4
2005	Vehicles/1000 Persons	16.5	13.5	0.6	5.1	3.8	39.5
	Annual Growth Rate (%)	28.7	23.7	5.2	6.8	3.2	18.8
	Elasticity to Economic Growth Rate	3.6	3.0	0.6	0.8	0.4	2.3
2010	Vehicles/1000 Persons	45.6	30.4	0.7	6.4	4.9	88.0
	Annual Growth Rate (%)	22.6	17.7	4.8	4.4	5.3	17.4
	Elasticity to Economic Growth Rate	3.2	2.5	0.7	0.6	0.8	2.5
2015	Vehicles/1000 Persons	85.5	46.1	0.9	7.8	6.3	146.7
	Annual Growth Rate (%)	13.4	8.7	4.7	4.3	5.2	10.7
	Elasticity to Economic Growth Rate	2.2	1.4	0.8	0.7	0.9	1.8
2020	Vehicles/1000 Persons	129.0	60.7	1.1	9.5	8.0	208.2
	Annual Growth Rate (%)	8.6	5.7	4.2	3.8	4.7	7.3
	Elasticity to Economic Growth Rate	1.7	1.1	0.8	0.8	0.9	1.5
2025	Vehicles/1000 Persons	177.1	75.9	1.3	11.0	9.7	275.0
	Annual Growth Rate (%)	6.5	4.6	3.4	3.0	3.9	5.7
	Elasticity to Economic Growth Rate	1.6	1.1	0.9	0.8	1.0	1.4
2030	Vehicles/1000 Persons	218.5	93.7	1.5	12.7	11.1	337.5
	Annual Growth Rate (%)	4.3	4.3	2.9	2.9	2.9	4.2
	Elasticity to Economic Growth Rate	1.1	1.1	0.7	0.7	0.7	1.0

Table 11 Economic Growth and Its Effect on Vehicle Growth Rate in Developed Countries

Country	GDP Growth Rate and Vehicle Elasticity	1960-1970	1970-1980	1980-1990	1990-1995
Japan	Per-capita GDP growth rate (%)	9.34	3.34	3.42	1.12
	Elasticity of cars and vans to GDP growth	3.53	2.75	0.99	4.25
	Elasticity of buses and trucks to GDP growth	2.61	1.12	1.24	-0.72
France	Per-capita GDP growth rate (%)	4.47	2.71	1.835	0.61
	Elasticity of cars and vans to GDP growth	1.78	1.44	0.93	2.06
	Elasticity of buses and trucks to GDP growth	0.17	0.98	3.20	2.16
U.K.	Per-capita GDP growth rate (%)	2.23	1.87	2.435	0.96
	Elasticity of cars and vans to GDP growth	3.14	1.39	1.49	1.24
	Elasticity of buses and trucks to GDP growth	0.40	0.37	2.78	-1.12
Canada	Per-capita GDP growth rate (%)	0.9	2.81	1.595	0.24
	Elasticity of cars and vans to GDP growth	3.39	1.15	0.54	-1.68
	Elasticity of buses and trucks to GDP growth	1.83	2.08	1.03	-15.07
U.S.	Per-capita GDP growth rate (%)	2.55	1.79	1.68	1.05
	Elasticity of cars and vans to GDP growth	0.96	1.15	0.01	-1.73
	Elasticity of buses and trucks to GDP growth	1.30	2.70	2.33	4.53

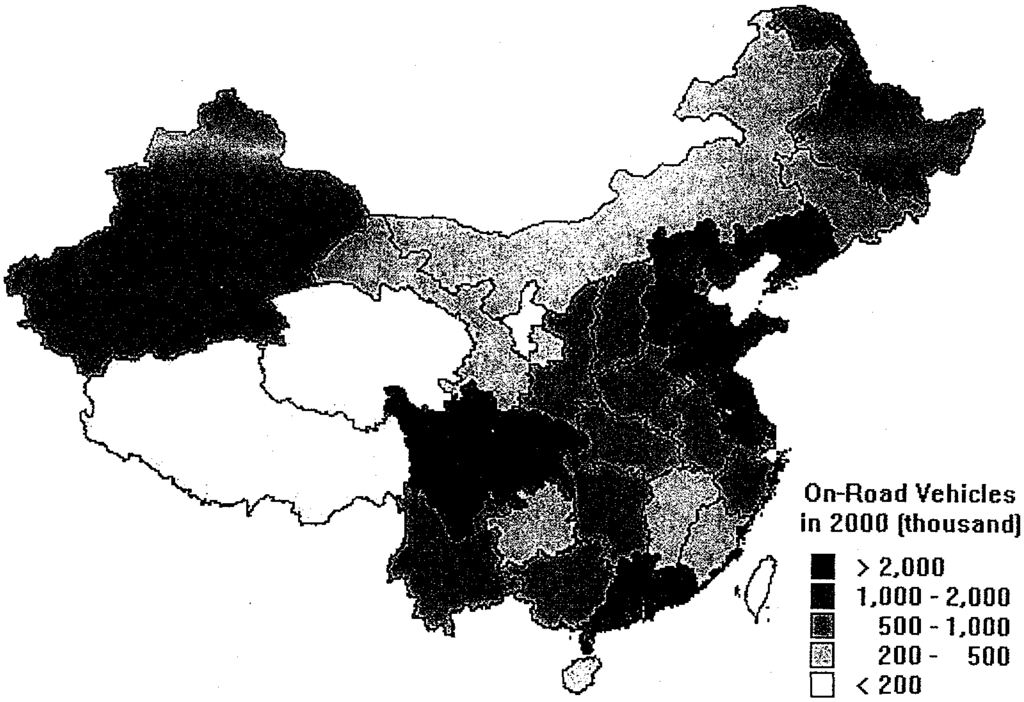
Source: World Bank (2000); Davis (1999); U.S. Bureau of Census (2000).

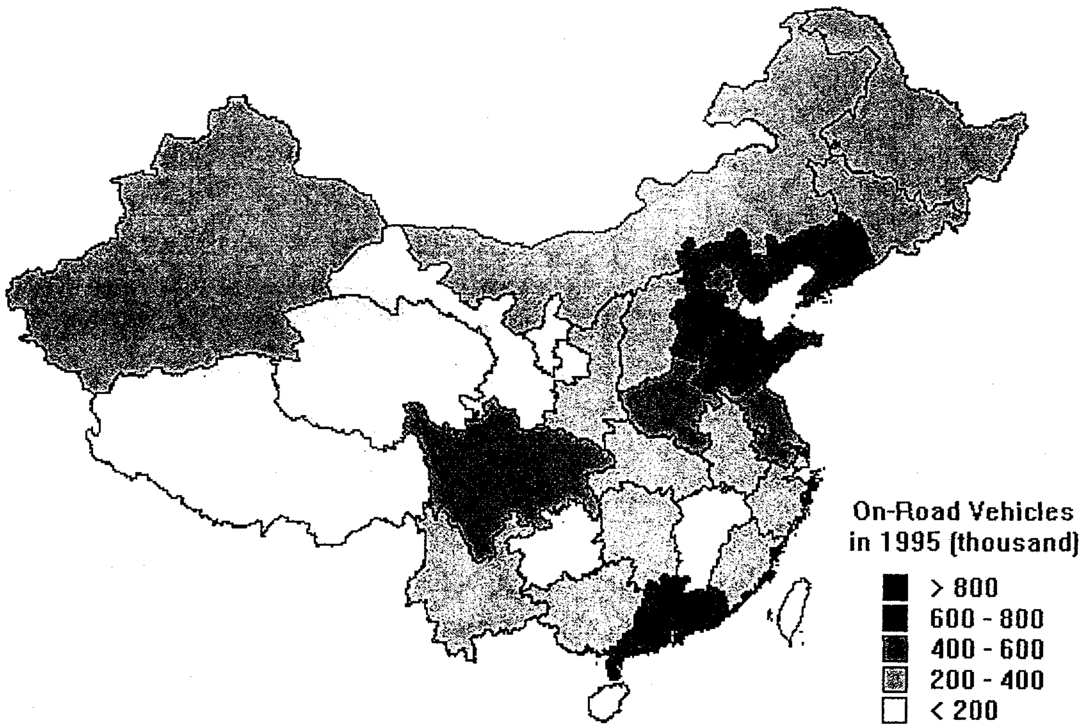
Table 12 presents vehicle populations in each of the three regions. At present, a large difference in vehicle population exists among the three regions. However, the difference will be reduced over time. By 2030, both all-vehicle population and passenger car population in the central region will exceed that in the eastern region. This is because (1) economy of the central region may eventually close gap with that of the eastern region, and (2) population in the eastern region will not increase much, while there is a great potential for population increase in the central region. Vehicle population in the western region will be still lower than that in either the east or the central region because economy there is still behind that in the other two regions.

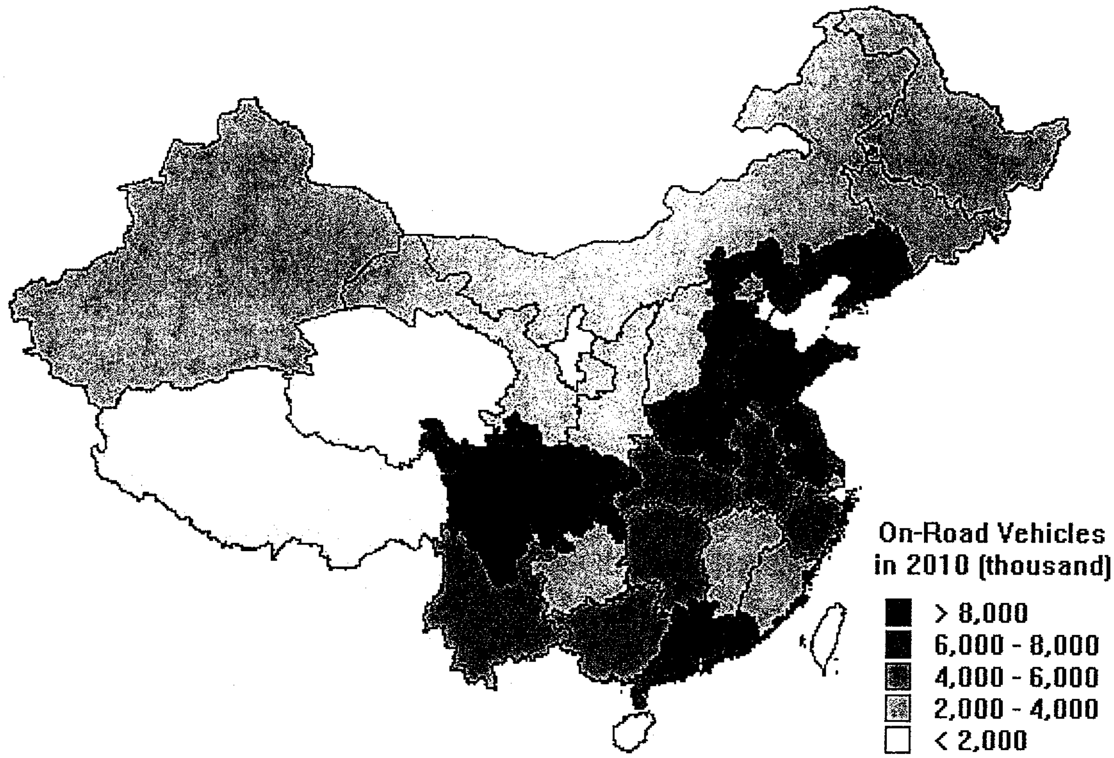
Table 12. Projected Vehicle Population in Three Chinese Regions (in millions)

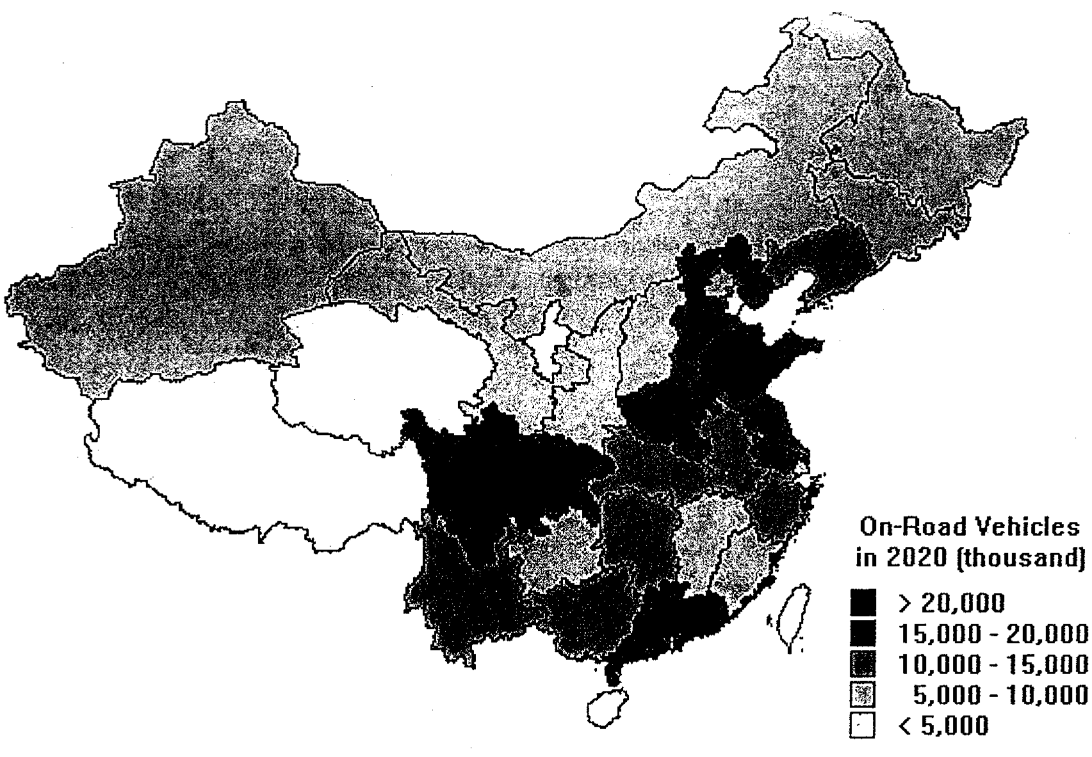
Year	1995	2000	2005	2010	2015	2020	2025	2030
	On-Road Vehicles							
Eastern	5.6	11.6	27.3	55.8	87.8	124.3	161.8	198.8
Central	3.3	6.5	16.8	44.8	83.0	123.3	171.1	216.9
Western	1.5	3.3	8.8	22.1	40.2	59.6	82.3	105.0
National	10.4	21.3	52.9	122.7	211.0	307.1	415.2	520.7
	Passenger Cars							
Eastern	1.1	3.7	12.6	31.0	54.4	84.1	110.7	137.2
Central	0.5	1.9	7.5	25.4	52.8	85.0	119.0	151.3
Western	0.2	1.0	4.0	12.5	25.4	40.8	56.8	72.8
National	1.8	6.6	24.1	68.9	132.5	209.8	286.5	361.2

On the provincial level (see figure 4), Guangdong province has the largest vehicle population currently and in the near future, followed by a few provinces in the eastern region. In the future, vehicle population in Sichuan and Sandong provinces will increase rapidly and catch up with Guangdong population. This is due to the large population base in these two provinces. By 2030, vehicle population in some central provinces will reach very high levels.


On-Road Vehicles
in 2000 (thousand)
> 2,000
1,000 - 2,000
500 - 1,000
200 - 500
< 200


On-Road Vehicles
in 1995 (thousand)
> 800
600 - 800
400 - 600
200 - 400
< 200


On-Road Vehicles
in 2010 (thousand)
> 8,000
6,000 - 8,000
4,000 - 6,000
2,000 - 4,000
< 2,000


On-Road Vehicles
in 2020 (thousand)
> 20,000
15,000 - 20,000
10,000 - 15,000
5,000 - 10,000
< 5,000

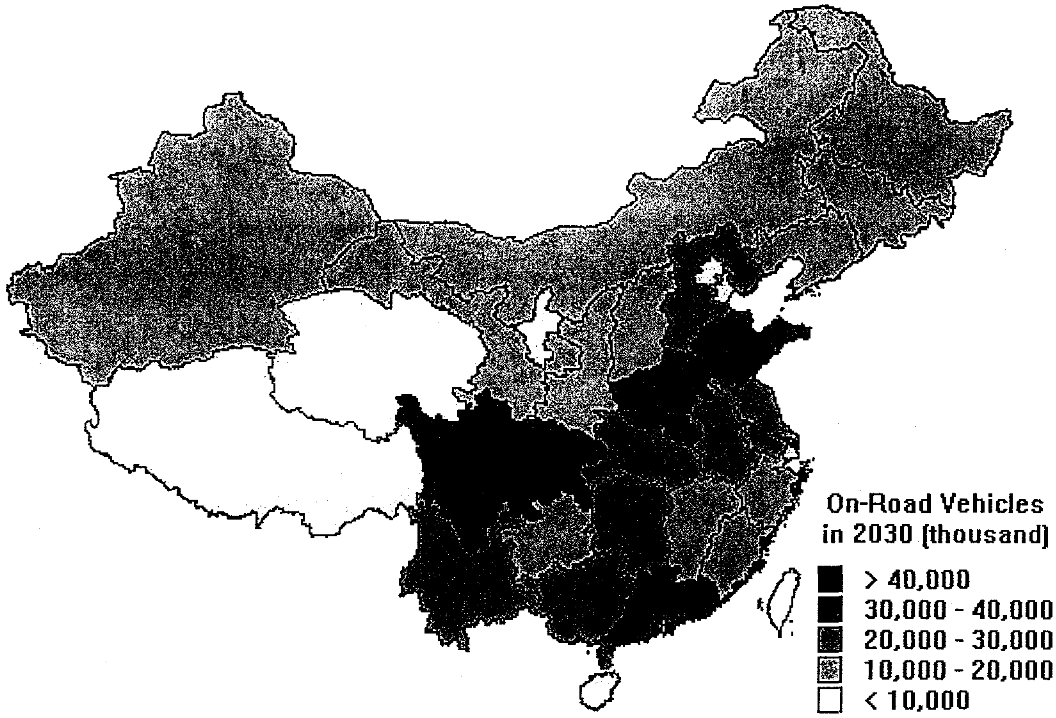


Figure 4. Projected Vehicle Population by Chinese Province

Total Energy Consumption by Chinese Motor Vehicles

Figures 5 and 6 present our projected annual fuel consumption by motor vehicles in China. Note that total fuel use, especially gasoline fuel use, may not increase as fast as vehicle population increases for two reasons. First, per-vehicle fuel consumption rates will decrease over time as advanced vehicles are introduced into Chinese vehicle fleets (Table 9). Second, as vehicle population increases, annual VMT per vehicle will decline (Table 8). This decline reflects the shift from commercial fleet-dominated passenger cars to family-dominated passenger cars. Nevertheless, by 2030, total fuel consumption by on-road Chinese motor vehicles will reach 557.4 million tons per year (gasoline and diesel total). In comparison, the current fuel consumption by U.S. on-road vehicles is about 525.0 million tons per year (EIA, 1999).

Figure 5 shows that most of gasoline will be consumed by passenger cars and vans (87.6% of cars and vans in 2030). On the other hand, most of diesel fuel will be consumed by heavy-duty trucks and more of them will be switched from gasoline to diesel over time.

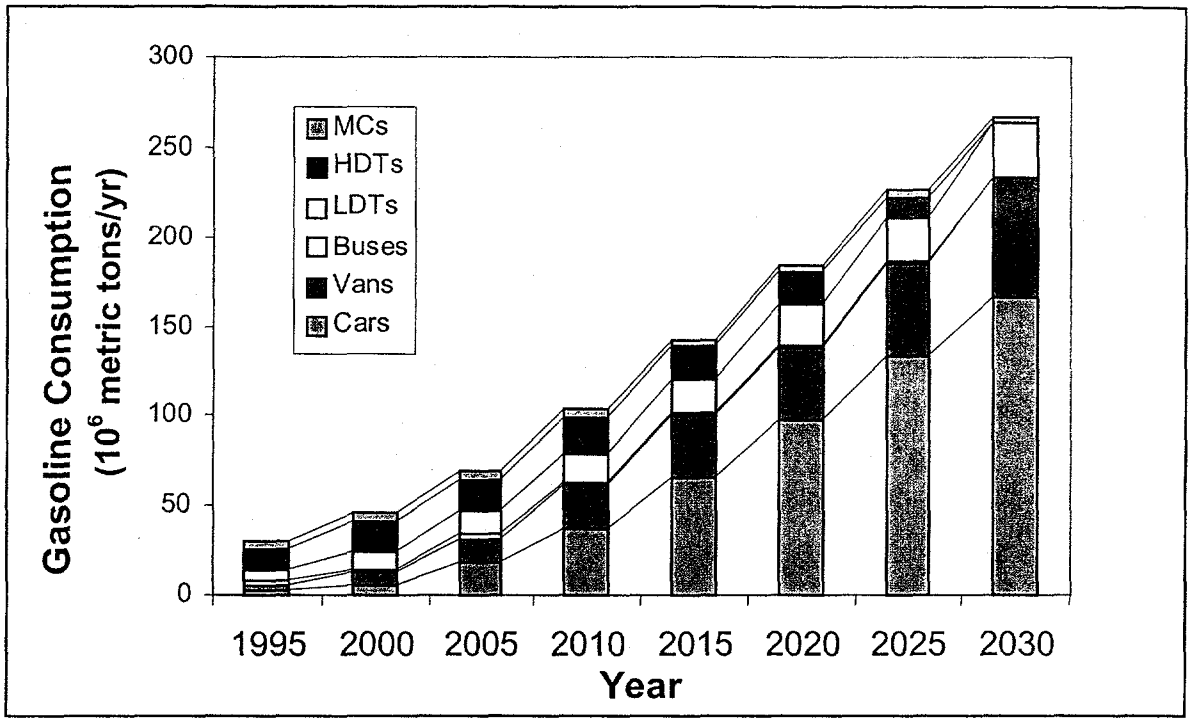


Figure 5. Projected Annual Gasoline Consumpiton by Chinese Motor Vehicles (million metric tons/year)

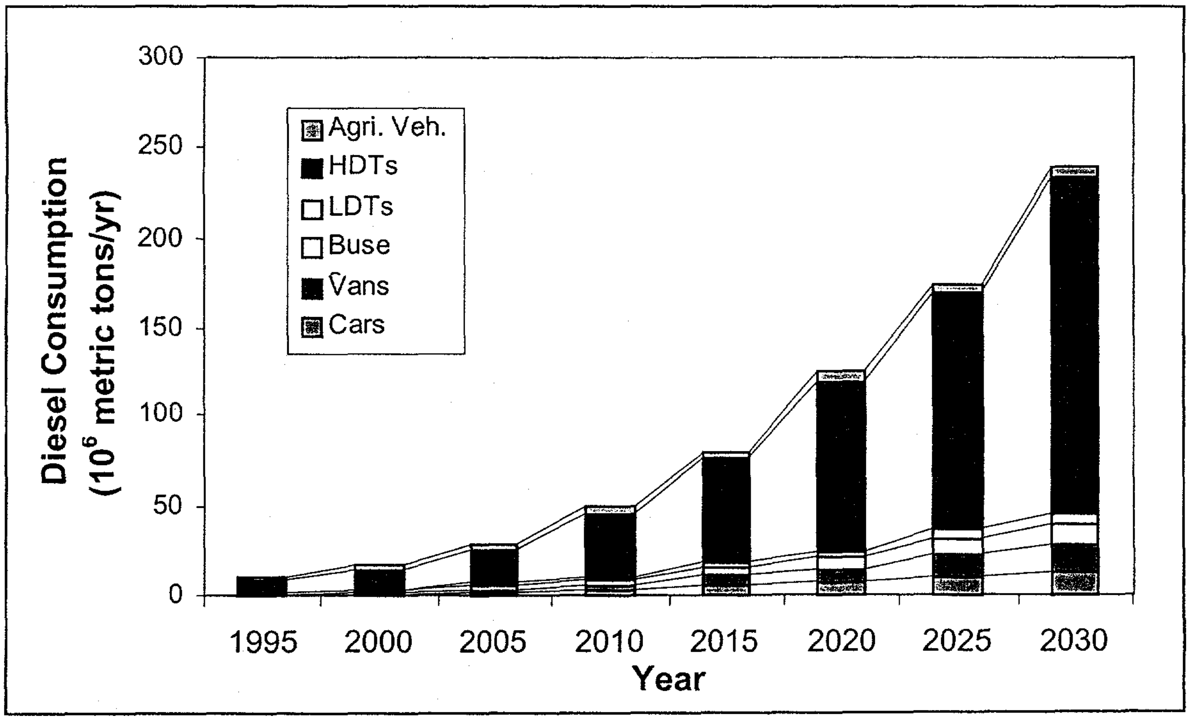
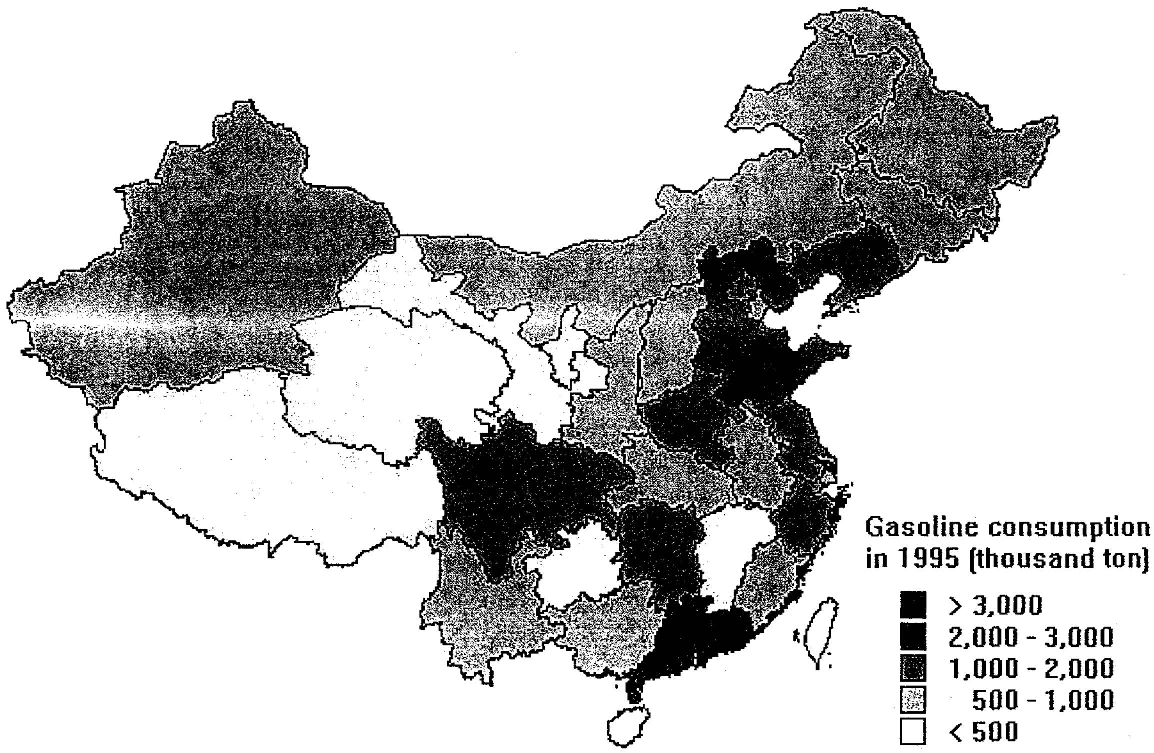
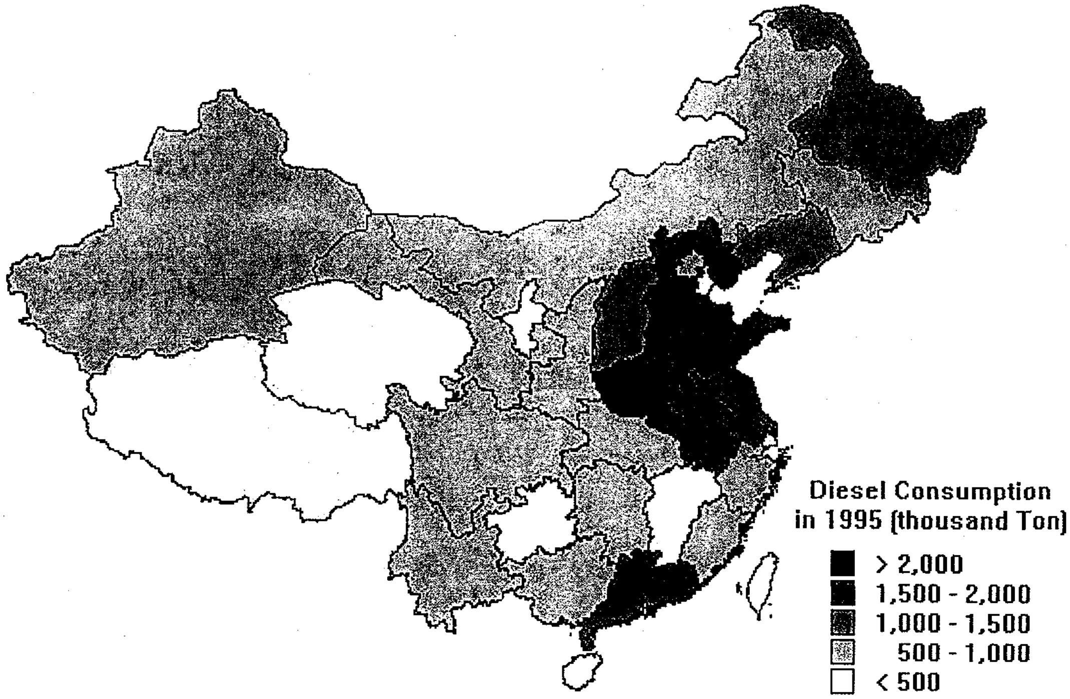


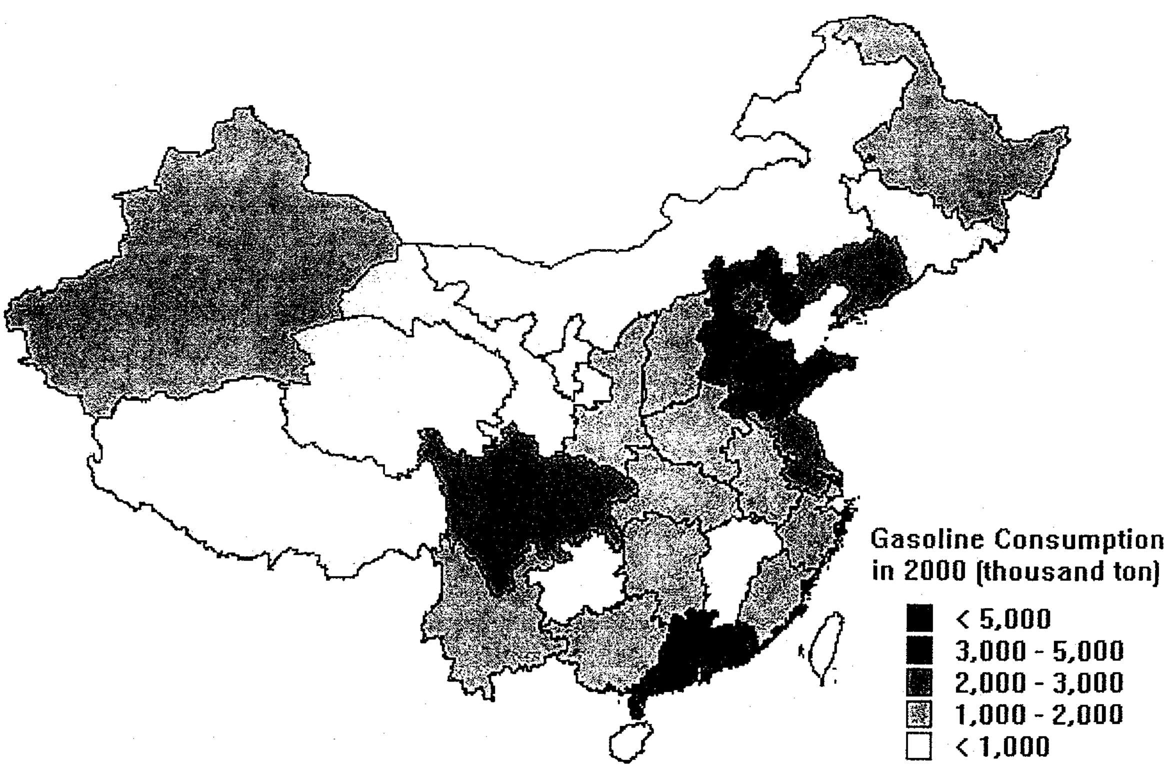
Figure 6. Projected Annual Diesel Fuel Consumption by Chinese Motor Vehicles (million metric tons/year)

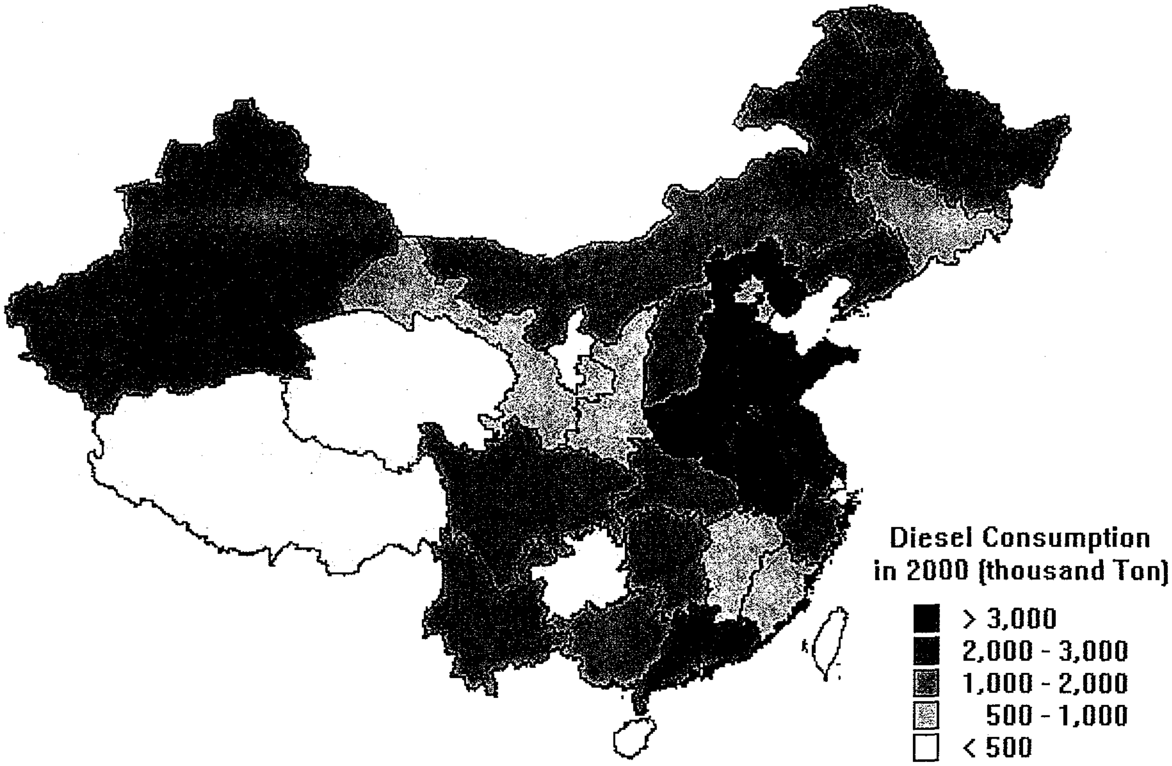
Table 13. Projected Motor Fuel Consumption in Three Chinese Regions (million metric tons/year)

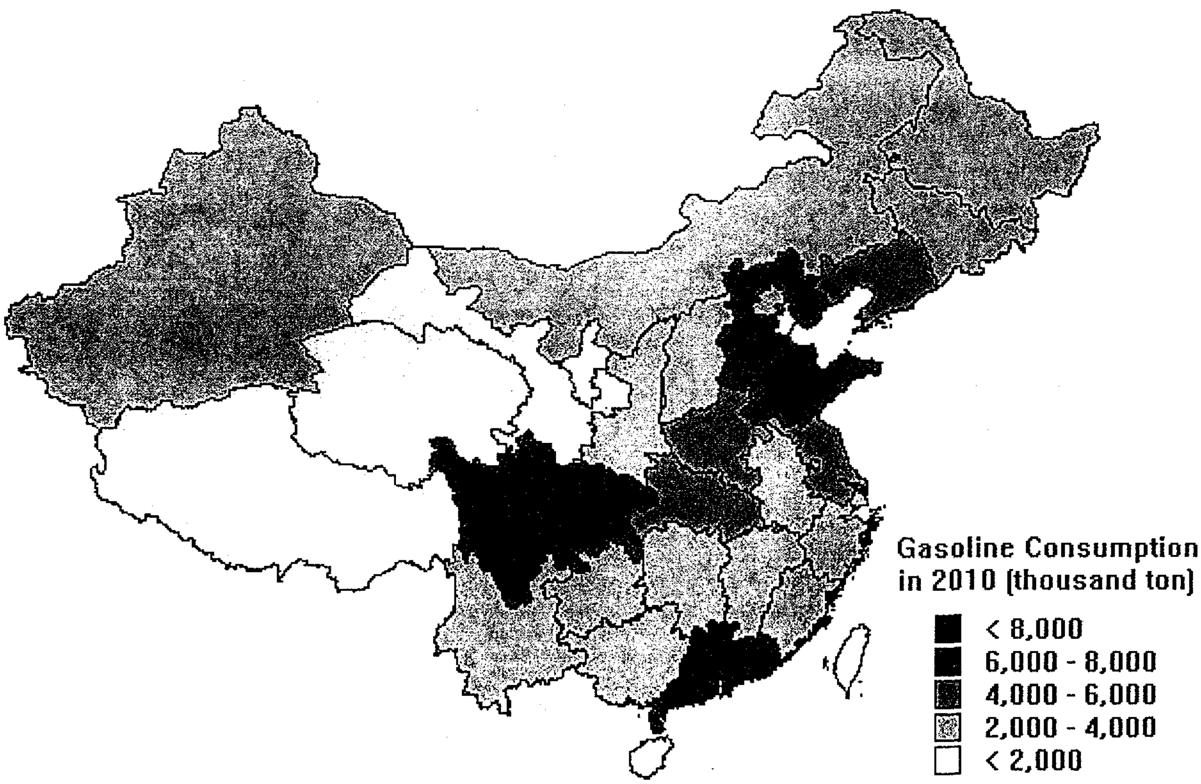
Year	1995	2000	2005	2010	2015	2020	2025	2030
	Gasoline (million metric tons/year)							
Eastern	17.2	24.9	35.3	48.5	62.3	77.2	90.6	103.8
Central	9.1	13.8	21.5	36.0	54.3	72.2	91.9	110.3
Western	4.2	6.9	11.0	18.1	26.8	35.4	44.6	53.6
National	30.6	45.6	67.9	102.6	143.4	184.9	227.1	267.7
	Diesel Fuel (million metric tons/year)							
Eastern	12.8	17.6	23.9	35.2	49.7	70.2	90.7	116.6
Central	11.8	15.7	20.8	30.1	43.1	62.9	85.3	115.8
Western	5.0	6.8	9.3	14.0	20.7	30.7	41.9	57.3
National	29.7	40.1	54.0	79.3	113.5	163.8	217.9	289.7

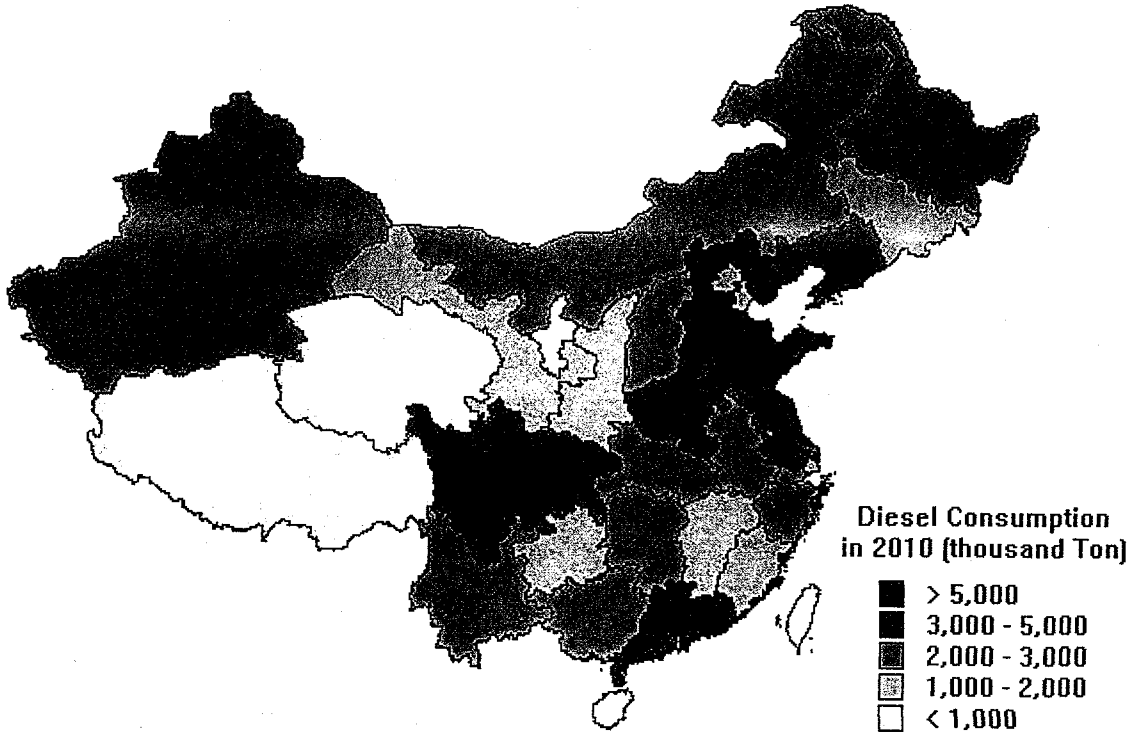


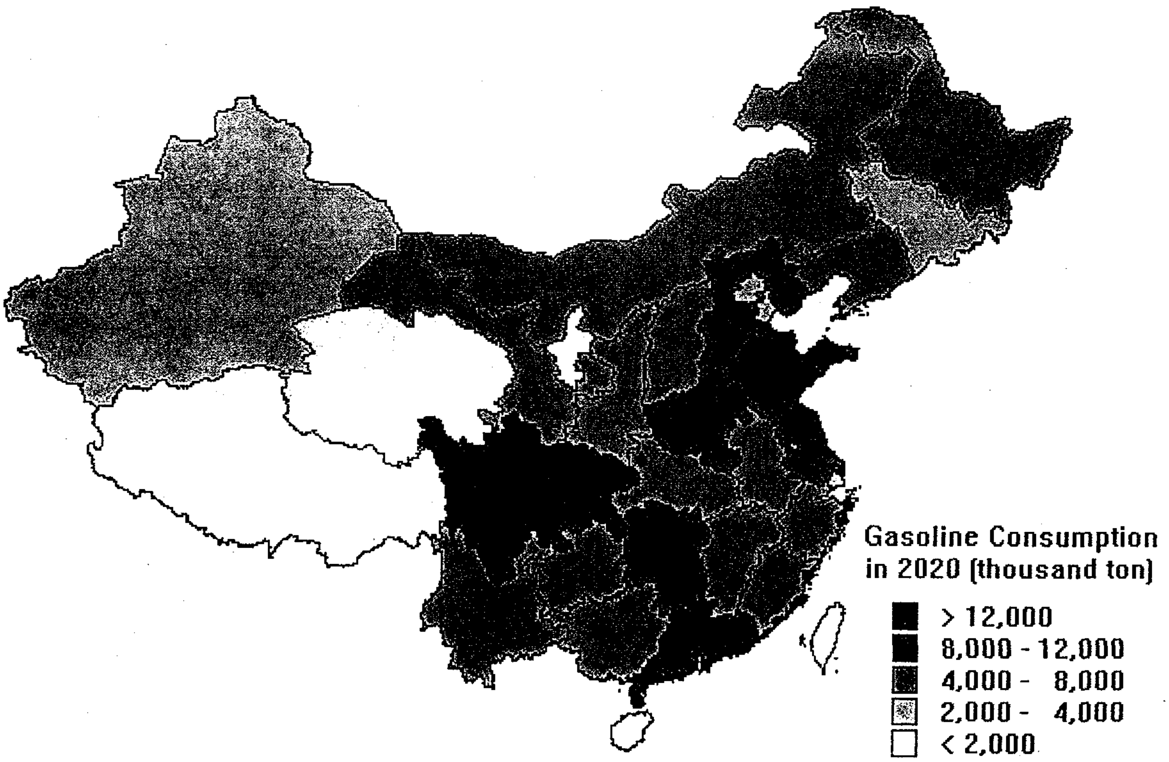

Diesel Consumption
in 1995 (thousand Ton)
> 2,000
1,500 - 2,000
1,000 - 1,500
500 - 1,000
< 500

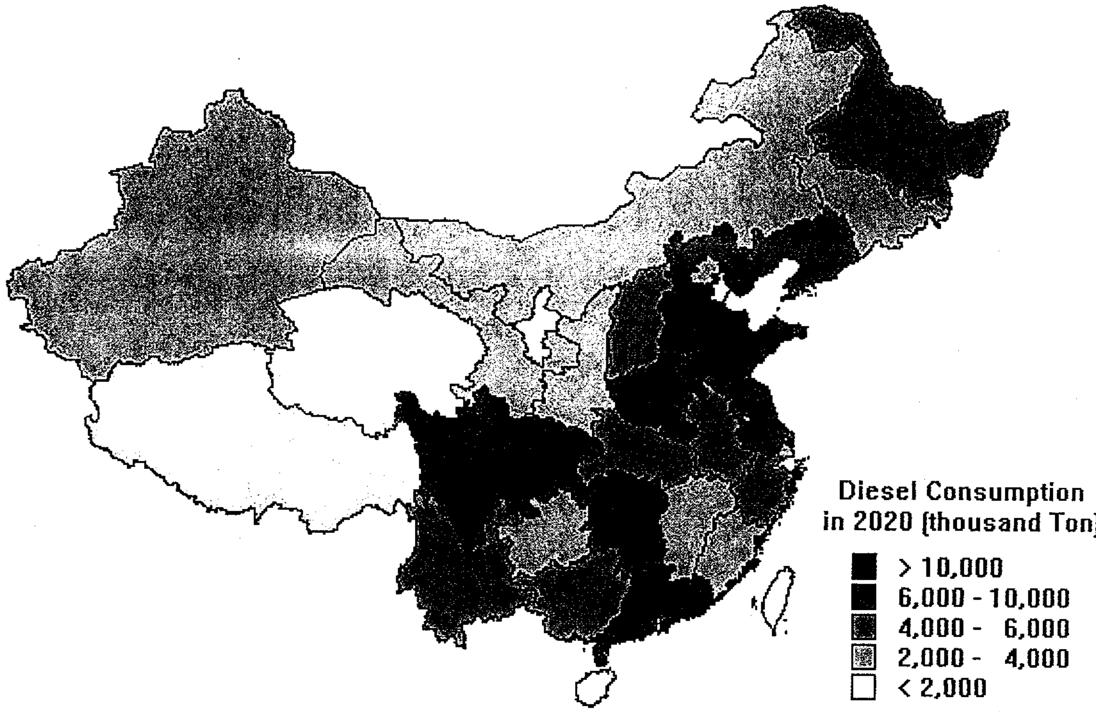

Gasoline Consumption
in 2000 (thousand ton)
< 5,000
3,000 - 5,000
2,000 - 3,000
1,000 - 2,000
< 1,000

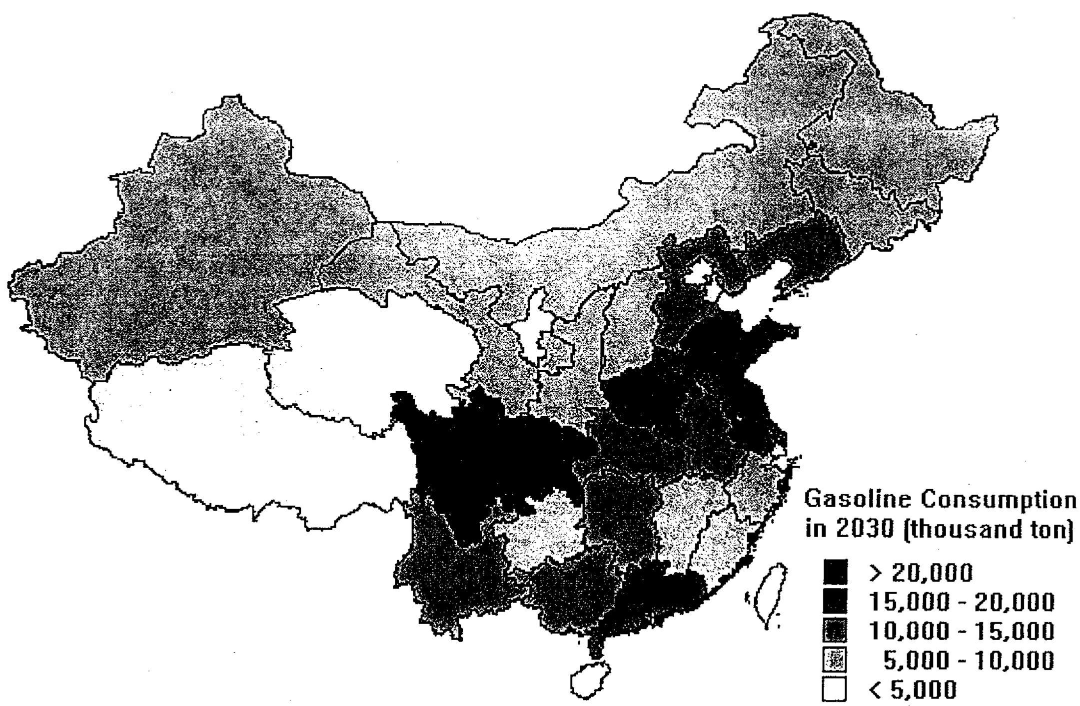

Diesel Consumption
in 2000 (thousand Ton)
> 3,000
2,000 - 3,000
1,000 - 2,000
500 - 1,000
< 500


Gasoline Consumption
in 2010 (thousand ton)
< 8,000
6,000 - 8,000
4,000 - 6,000
2,000 - 4,000
< 2,000


Diesel Consumption
in 2010 (thousand Ton)
> 5,000
3,000 - 5,000
2,000 - 3,000
1,000 - 2,000
< 1,000


Gasoline Consumption
in 2020 (thousand ton)
> 12,000
8,000 - 12,000
4,000 - 8,000
2,000 - 4,000
< 2,000


Diesel Consumption
in 2020 (thousand Ton)
> 10,000
6,000 - 10,000
4,000 - 6,000
2,000 - 4,000
< 2,000


Gasoline Consumption
in 2030 (thousand ton)
> 20,000
15,000 - 20,000
10,000 - 15,000
5,000 - 10,000
< 5,000

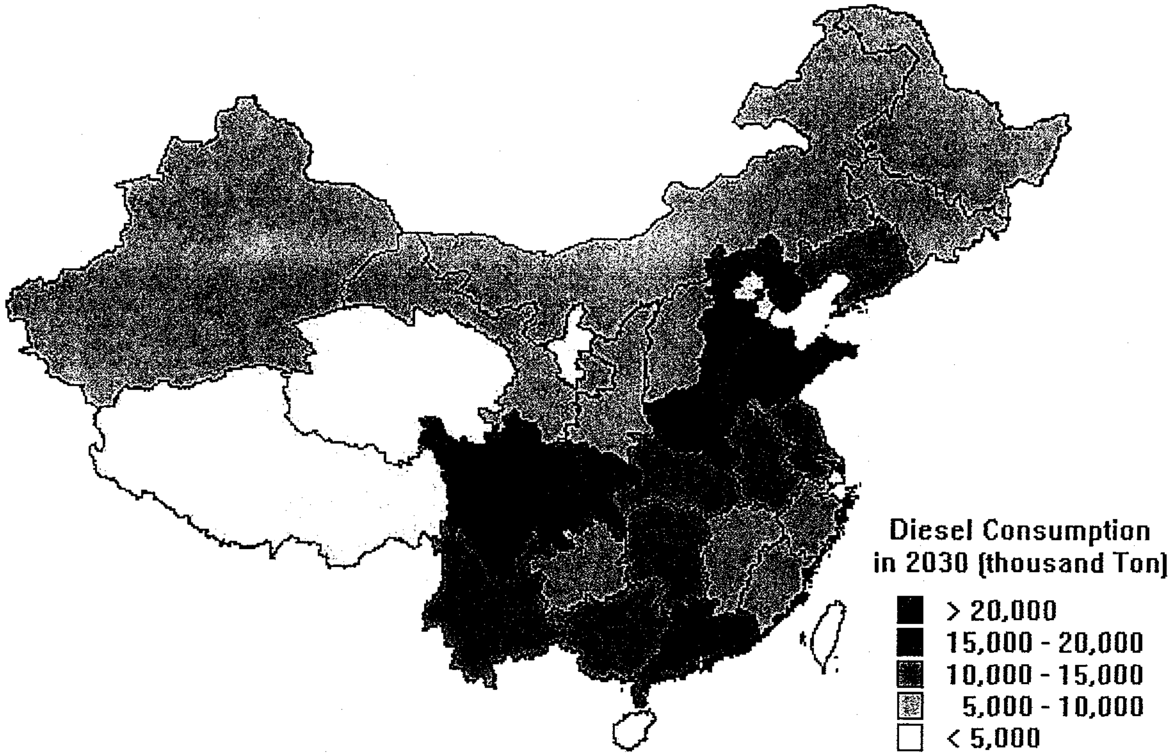


Figure 7. Projected Annual Gasoline and Diesel Consumption by Province in China

Motor fuel consumption by each of the three Chinese regions is presented in Table 13. The differences in fuel consumption among the three regions will become smaller over time, as the difference in vehicle population will become smaller. However, the split between gasoline and diesel consumption is different among provinces (Figure 7). Gasoline is mainly consumed in eastern provinces and in Sichuan province, whereas more diesel is consumed in northeast provinces, which are heavily industrialized and have high population of heavy-duty diesel trucks. On the other hand, the split between gasoline and diesel consumption in eastern and central provinces is about even.

CO_2 Emissions from Chinese Motor Vehicles

Figure 8 presents CO_2 emissions from Chinese motor vehicles. By 2030, total annual CO_2 emissions will reach 1,781.5 million metric tons per year, about 9 times the 1995 emission level. This represents an annual growth rate of about 6.5% during the 35-year period. In comparsion, the annual CO_2 emissions from current U.S. motor vehicles are 1,652 million metric tons (U.S. EPA, 1999). That is, according to our projection, the total Chinese motor vehicle CO_2 emissions in 2030 can reach the current U.S. level.

On the provincial level, the provinces with great gasoline or diesel consumption will obviously generate more CO_2 emissions. That is, Guangdong, Sichuan, and Shandong provinces will be the top three CO_2 emitting provinces.

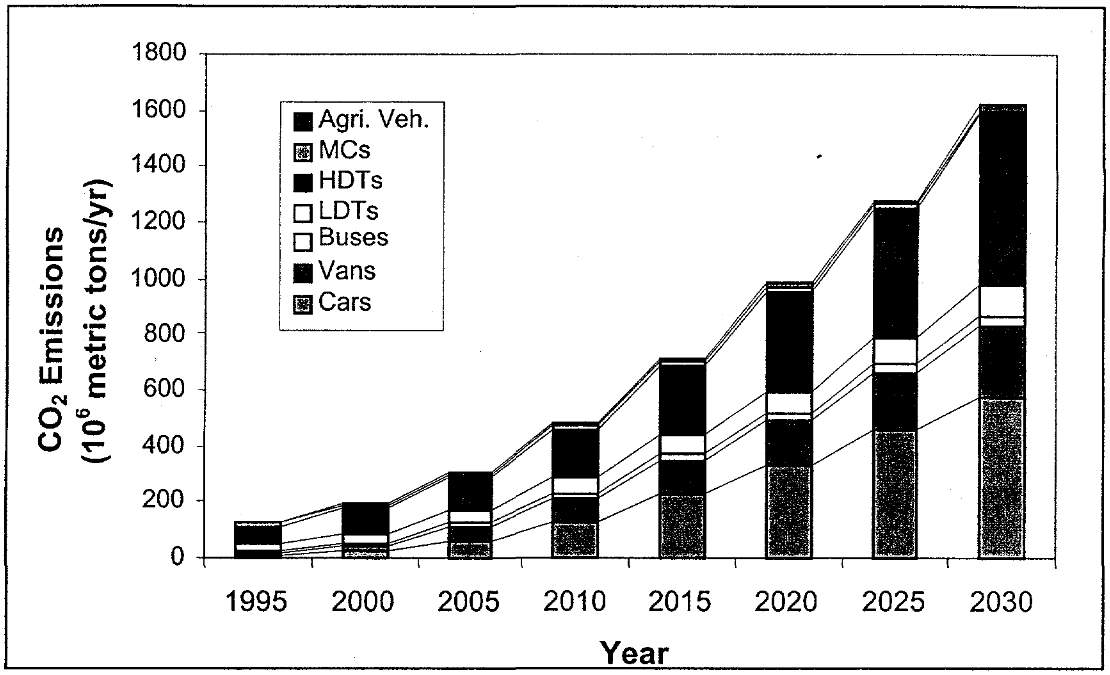


Figure 8. Projected Annual CO_2 Emissions from Chinese Motor Vehicles (million metric tons/year)

Conclusions

Motor vehicle population in China is undergoing and will continue to undergo rapid growth because of economic development and population growth. As a result of the rapid growth, motor vehicle fuel consumption and CO_2 emissions in China will increase dramatically in the next 30 years. Fuel consumption and CO_2 emissions by Chinese motor vehicles in 2030 could reach those of U.S. current on-road motor vehicles. This will pose a great challenge to China, and to the world, if countries will ever agree to stabilize, or even reduce, global CO_2 emissions.

Vehicle population and fuel consumption differ significantly among provinces, though the difference will become smaller over time. The problems of short of fuel supply and urban air pollution, as being experiencing in eastern provinces, will be experienced in central and western provinces.

Our projections reflect our assumptions about economic growth, population growth, and growth in vehicles per 1000 persons in China in the next 30 years. This represents one of the many plausible scenarios for Chinese vehicle population growth and resultant fuel consumption and CO_2 emissions. Results presented in this paper should be treated as what-if scenario results.

Acknowledgments

The research effort of this paper was funded by International Institute of Applied Systems Analysis. The authors are solely responsible for the content of the paper. The submitted manuscript has been authored by a contractor of the U.S. Government, under contract no. W-31-

109-ENG-38. Accordingly, the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes.

References

China Department of Mechanical Industry, 1998, *Analysis on the Program to Introduce Cars into China's Families*, Beijing, China.

China Department of Mechanical Industry, 1996, *Reference for Automobile Industrial Developing Plan*, Beijing, China.

China Environmental Protection Administration, 1997, *China's Strategies for Controlling Motor Vehicle Emissions, Summery Report*, Beijing, China

China's International Science Center, 1998, *Study on the Technical Strategies for Vehicle Emission Control in China,* Beijing, China.

China National Statistics Bureau, 1990-1998, *China Statistics Yearbook*, Beijing, China (each year).

Energy Information Administration, 1999, Petroleum Supply 1998, DOE/EIA-0340(98)/1, Washington D.C. June.

Davis, S. C. 1999, *Transportation Energy Data Book, 19th Edition*, Oak Ridge National Laboratory, Oak Ridge, TN., Sep.

Fu, L. et al., 1999, *Vehicle Emissions in Highway Transportation Systems in China*, Tsinghua University, Beijing, China.

He, D., 1999, *Study of Urban Vehicular Pollution and Emission Control Target,* Ph.D. Dissertation, Tsinghua University, Beijing, China.

Lee, S. et al., 1999, *Rapid Motorization in the Largest Countries in Asia: Implication for Oil, Carbon Dioxide and Transportation*. International Energy Agency, Paris, France.

Song, N., et al., 1994, *Incorporation of Environmental Consideration in Energy Plan in China -- Report of Automobiles*, Beijing Automobile Research Institute, Beijing, China.

Statistic Yearbook of China's Automobile Industry, 1996, Beijing, China.

U.S. Environmental Protection Agency, 1999, Inventory of U.S. Greenhouse Gas Emissions and sinks: 1990-1997, EPA 236-R-99-003. Washington, D.C., April.

U.S. Bureau of Census, 2000, *World Population Information*, Washington D.C.

Wang, C. et al., 1999 *An Engineering Study for the Development and Marketing of Personal Use Cars in China (drafted report)*, Shanghai Jiaotong University, Shanghai, China.

World Bank, 2000, Global Development Network Growth Database, http://www.worldbank.org/research/growth/GDNdata.htm