Seminar on Global Warming and Road Transportation: The Impact of Motorization in Fast-Growing Developing Nations such as China and India

Research Paper

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FOREWORD

This seminar intends to shed light on how much impact motorization in fast growing economies like China and India have on global warming, and the need to address this issue in a global setting. If China's economy grows at the current speed and motorization takes off on a potentially unprecedented scale, energy consumption and CO_2 emissions from road transportation in China, which remain relatively low now, will climb sharply and have a bigger share in total energy consumption and CO_2 emissions in the world. The same is likely to happen in India in the longer term.

Yet the two countries are not covered by the Kyoto protocol, and not legally bound to reduce CO_2 emissions. Kyoto University's Institute of Economic Research and JITI have developed a projection model of future CO_2 emissions from road transportation in China. This model will show us the significant impact of rapid motorization in China on global warming. In our presentations, we will also shed a light on India's road transportation, and discuss the difference and similarities between these two countries.

Specific numerical predictions concerning China help us to understand the urgency and necessity of measures for developing countries in reducing carbon dioxide emissions from worldwide road transportation.

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The Japan International Transport Institute

Table of Contents

1. Major Objectives and Areas of Research 1
2. Current Status of Road Transportation in China 3
  2.1 Factors Affecting Transportation in China 3
    2.1.1 Economic growth 3
    2.1.2 Transportation 4
    2.1.3 Surface transportation 7
      2.1.3.1 Rail transportation 7
      2.1.3.2 Road Transportation 9
      2.1.3.3 Vehicle Preference and Use 12
  2.2 China's Motorization at Take-Off Stage 16
3. Future Projection of CO_2 Emissions from Road Transportation in China 19
  3.1 Forecasting method 19
  3.2 Results 20
4. Verification of Model Estimates (Comparison with Energy Consumption Statistics) 22
5. The Future of Indian Road Transport and CO_2 Emissions 25
  5.1 Travel and Vehicle Patterns in India 25
  5.2 Comparisons with China 28
  5.3 Travel and Emissions Forecasts 29
  5.4 Future of India's Road Transportation Sector (Outlook in comparison with China) 31
6. Future Research Directions 32

1. Major Objectives and Areas of Research

An examination of each country's share of global CO_2 emissions, a major cause of global warming, is informative. The United States has the largest contribution at 24 percent, followed by China's 14%, and India comes in the fifth place with about 4%. Developing countries including China have shown dramatic economic growth and have strong potential to leap forward in their economic development in the early half of this century. Consequently, a large amount of CO_2 emissions from developing countries are expected.

Japan and Russia are the two nations which have ratified the Kyoto Protocol to the UN Framework Convention of Climate Change in response to global warming and are among the top five CO_2 emitters. Even if all emissions were reduced in these two nations or reduction in emissions from the EU 15 countries put together, China still has a larger share of CO_2 emissions. The future potential of China is obviously even greater. The fifth largest contributor, India, is rapidly approaching the level of Japan, the fourth largest contributor (see Table 1-1).

Table 1-1 Emission Ratios of Five Largest CO_2-Emissing Countries (2002)

	1	2	3	4	5	
Country	United States	China	Russia	Japan	India	15 EU countries
Ratio (%)	24.3	14.0	6.2	4.9	4.4	13.3

Source: OECD

For these reasons, it is necessary for developing countries to implement CO_2 restraint measures for the effective prevention of global warming. After all, greenhouse gases, whether they are from developed countries or developing countries, contribute to global warming. There is no doubt about the need to keep in check CO_2 emissions, whether their origin is in a developed country subject to the Kyoto Protocol, other developed countries, or developing countries.

Furthermore, we have to keep in mind that if progress is to be made in measures to reduce CO_2 from fixed emission sources such as power plants, it will become crucial to work out measures to cope with emissions from the transport sector, particularly the road transportation sector that now accounts for about one-fourth of the world's CO_2 emissions. When working out measures to reduce CO_2 emissions from road transportation sectors throughout the world, it is necessary to study how fast motorization will progress in developing countries. In addition, technical problems, such as the difficulty of monitoring individual motor vehicles, and infrastructure problems such as the establishment of a fuel supply networks requiring large amounts of capital, need to be addressed

For these reasons, this seminar will focus on road transportation in China, a rapidly growing economy. We will present a forecast model and its estimates of CO_2 emissions from China's road transportation sector up to 2030. The model explicitly compares China with Japan on numerous parameters, such as economic indicators. The validity of the results from the model is also assessed in this paper. The results of the model and other analyses highlight the need and urgency to reduce CO_2 emissions from road transportation in developing countries. Based on these findings from China and using a futures analysis, India's present and future CO_2 emissions from road transportation sector are examined. We compare India and China in terms of motorization, economic development, and greenhouse gas emissions. Finally, we discuss the direction of a future framework on measures to reduce CO_2 emissions from worldwide road transportation.

2. Current Status of Road Transportation in China

2.1 Factors affecting road transportation in China

2.1.1 Economic growth

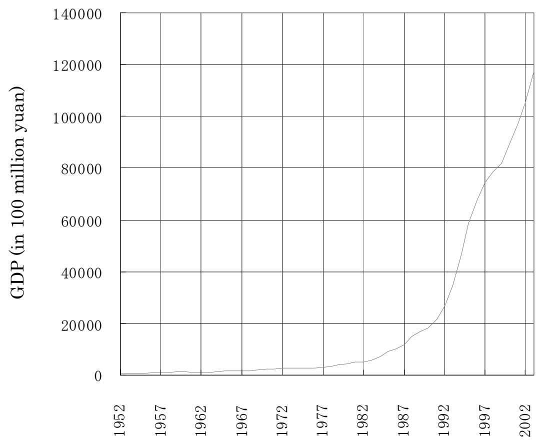


Figure 2-1 Changes in China's GDP

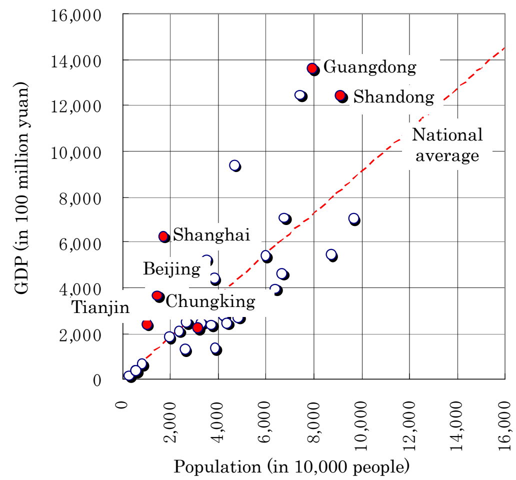


Figure 2-2 Correlation between Population and GDP in Provinces and Major Cities

China stepped up its growth in the late 1970s. In the 1980s, China entered a high-growth era with annual GDP growth rates of more than ten percent. Even with the belt-tightening policy of 1989 and fallout from the Tiananmen Square Incident, China's economy generally continued to sail along. It slowed down from 1995 to 1999, even dropping to a 5% growth rate for a brief period, but accelerated again at more than 8% from 2000 - see Figure 2-1.

Disparities in economic growth by region are important for any analysis of China's growth and development. China's overall GDP per capita stands at little less than 10,000 Yuan in 2003. However, GDP per capita in the capital, Beijing, reaches 32,000 Yuan. In Shanghai, a center of commerce, it reaches 46,000 Yuan. Figure 2-2 plots the relation between population and GDP of China's provinces and large cities in 2003. The line connecting from the origin outward is surrounded by small circles representing GDP per capita for each province or city (the horizontal axis represents the population in thousands). Currently, GDP per capita in most of the provinces does not deviate from the national average. However, cities, especially larger and coastal ones, clearly are wealthier. Economic growth and rapid urbanization will lead to the widening of the differences of wealth between rural and urban areas.

2.1.2 Transportation

Any analysis of transportation in China requires an understanding of past and present trends and estimating reasonable future pathways from these trends. It is important to break down China's domestic transportation into passenger and freight transportation. Figure 2-3 shows changes in passenger transportation volume in China. Although the belt-tightening policy (or "improvement and arrangement" policy) in 1989 and the Tiananmen Square Incident affected passenger transportation volume, generally speaking, it has rapidly risen from the late 1970s when economic reforms were introduced. Figure 2-4 shows changes in freight transportation volume in China. The curve indicates the same pattern of growth as passenger transportation. Both passenger and freight transportation consistently increased for the past two decades as China's economy grew.

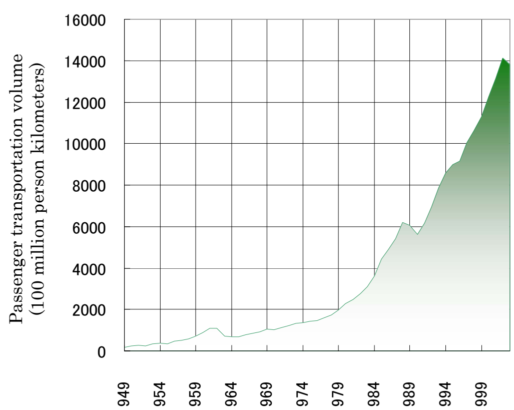


Figure 2-3 Changes in Passenger Transportation Volume in China

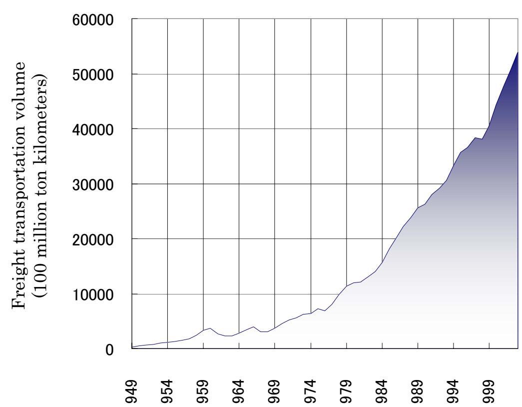


Figure 2-4 Changes in China's Freight Transportation Volume

Figure 2-5 shows changes in year-on-year growth rates of GDP and passenger and freight transportation volumes

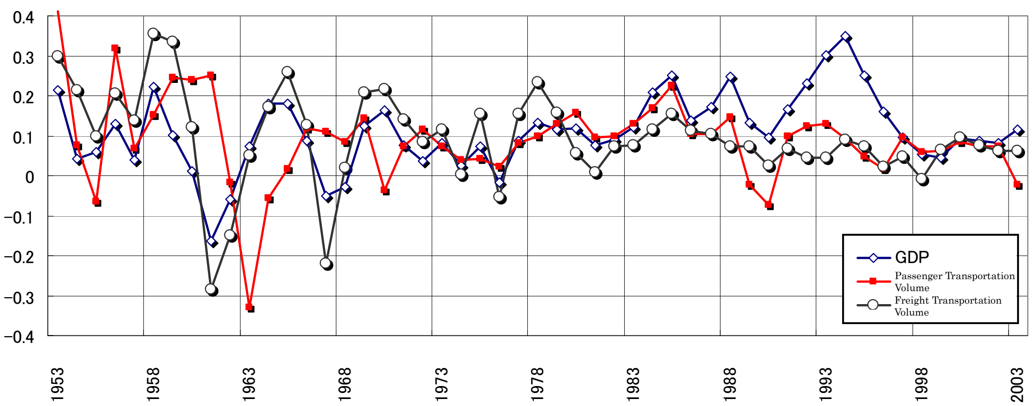


Figure 2-5 Changes in Year-on-Year Growth Rates of GDP and passenger and freight transportation volumes

As seen in Figure 2-5, the growth rate of freight transportation volume was consistently lower than that of GDP since the late 1970s. In contrast, the growth rate of passenger transportation volume shows close correlation with that of GDP. One explanation for the lower growth rate of freight transportation points to difficult-to-identify bottlenecks in handling traffic and increasing capacity and may include the fact that freight transportation services could not meet increases in demand due to rapid economic growth.

Next, we look at traffic volume by mode of transportation. Figures 2-6 and 2-7 show changes in traffic volume by each mode of transportation in China. Railroads had a dominant share of passenger transportation at the outset. Road transportation passed railroads in the 1990s. As of 1999, road transportation accounts for half of total passenger traffic volume. As for freight transport, since the first half of the 1980s, water transportation (domestic coastal and river transportation) has surpassed that of rail. For freight surface transportation, we find that the share of railroads has been consistently larger than that of road transportation.

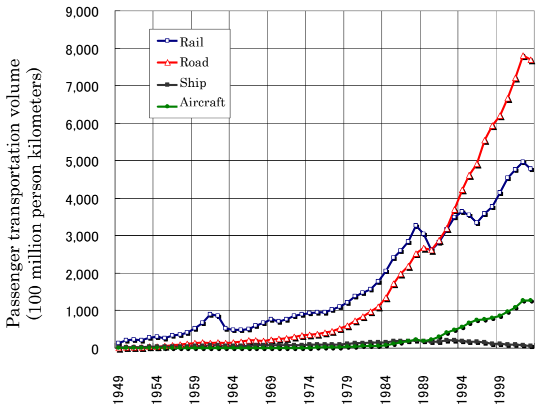


Figure 2-6 Changes in Passenger Transportation Volume by Mode of Transportation

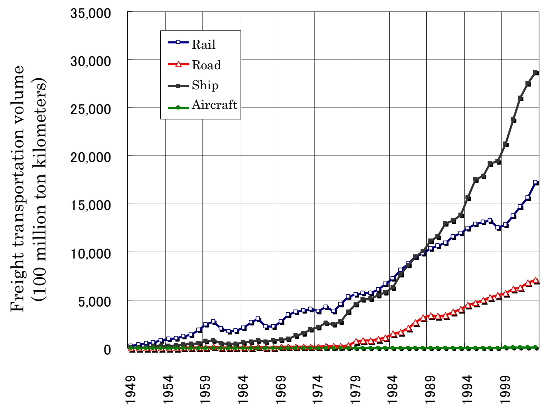


Figure 2-7 Changes in Freight Transportation Volume by Mode of Transportation

China's economy is still at the fast developing stage. China is expected to continue to grow at high rates in the foreseeable future. In fact, numerous projections and case studies on China's future economic growth forecast that the Chinese economy will continue to grow at 5 to 7 percent annually for 10 to 30 years. Although there are slight differences between the growth rates of traffic volume and GDP, past experience shows that passenger and freight traffic volume increase with economic growth and total traffic volume will also grow at similar rates.

2.1.3 Surface transportation

2.1.3.1 Rail transportation

Railroads are second to road transportation modes in terms of combined passenger and freight transportation volume. In terms of capacity and size, railroads are still one of the most important transportation modes in China. Figure 2-8 shows changes in the total length of railroad tracks. More than 90 percent of railroad tracks are controlled by the national railroad and their total length has continued to be extended over the past half century.

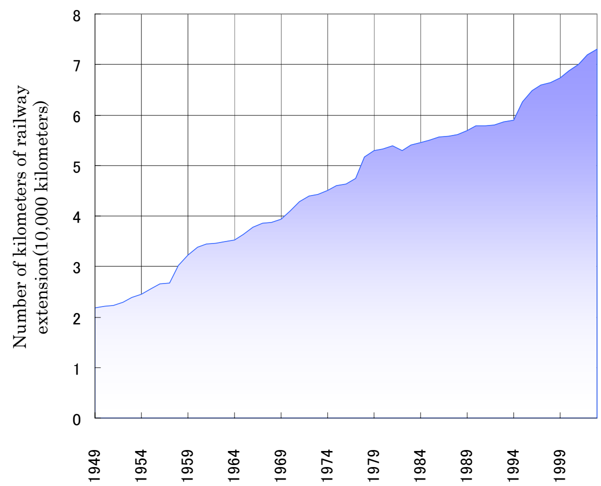


Figure 2-8 Length of China's Railroads

The busiest passenger line runs between Beijing and Guangzhou with traffic volume reaching 132.22 million passengers or 71 billion passenger kilometers in 1999. This line accounts for one-sixth of total passenger traffic volume. It is followed by such lines connecting big cities as the Beijing-Tianjin line, and Dailian-Harbin line. Passenger railroad transportation plays a major role as the primary intercity transportation mode. Growing urbanization is likely to impact passenger transportation with high growth rates for this segment of travel activity in the future.

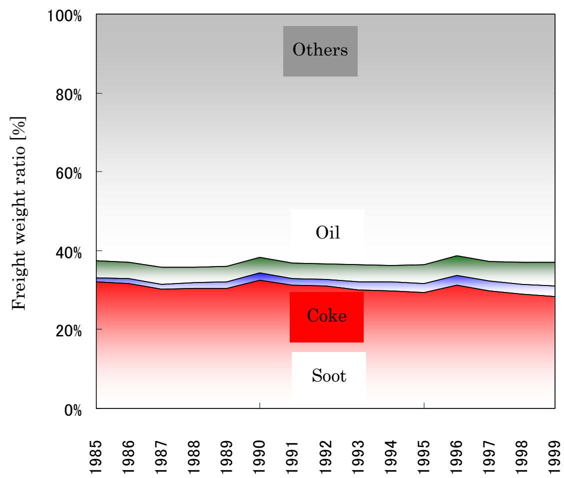


Figure 2-9 Percentage of Fuels in Rail Transportation Volume

Intercity transportation plays a much reduced role in freight transportation. The type of goods transported on rail is critical. Figure 2-9 depicts the weight percentage of total freight by rail for different commodities. It is clear from this chart that nearly 40 percent of the goods transported on rail are fuels such as coal and oil. Railroads play a crucial role in the transportation of domestic energy and overall economic growth in China. For example, coal accounts for more than 30 percent of total transportation volume by rail and it is transported throughout China from primarily Northwestern coal-mining regions, mainly Shanxi province and the Inner Mongol Autonomous Region (see Table 2-1). Rail is also used for transportation of oil from main oil fields in Heilongjiang, Shangdong and Liaoning.

Table 2-1 Rail Transportation Volume by Region (Shipping Volume)

[10,000 tons]

		Beijing	Tianjin	Shanghai	Main coal producing areas			Main oil producing areas			Others
					Shanxi	Inner Mongol	Shenhsi	Heilongjiang	Shangdon	Liaoning	
1990	Total shipping volume	5,341	5,563	2,283	4,930	5,187	3,053	11,009	9,185	16,634	83,024
	Coal shipping volume	2,144	1,560	190	2,333	1,969	1,381	4,694	4,664	6,287	37,648
1995	Total shipping volume	6,446	7,147	2,790	4,609	4,743	2,919	10,030	9,952	16,593	94,117
	Coal shipping volume	1,924	2,967	365	1,928	1,638	1,181	4,338	5,157	6,341	41,518
1999	Total shipping volume	5,246	6,580	2,008	4,208	4,568	3,055	9,436	11,249	15,432	95,099
	Coal shipping volume	1,646	2,843	268	1,718	1,537	1,010	3,865	5,927	5,805	40,298

China's government regards railroads as the most important transportation mode for future economic growth. But railroads require large levels of capital and investment for development and maintenance of tracks. They also require significant planning and lengthy completion times. China cannot extend its railroad network fast enough to meet expected demand. The resulting gap is largely filled by road transportation.

2.1.3.2 Road transportation

Road transportation, generally speaking, has been on the rise for both passenger and freight. An exception was a dip around 1989 similar to transportation as a whole. (See Figures 2-10 and 2-11.) Road transportation accounts for the largest share of passenger travel and accounts for more than half of total passenger transportation. Nevertheless, it only accounts for fifteen percent of freight transportation volume. This is in clear contrast with Japan where trucks are heavily used. As explained above, this phenomena ties in with the fact that a large part of China's fuel supply is transported by railroads.

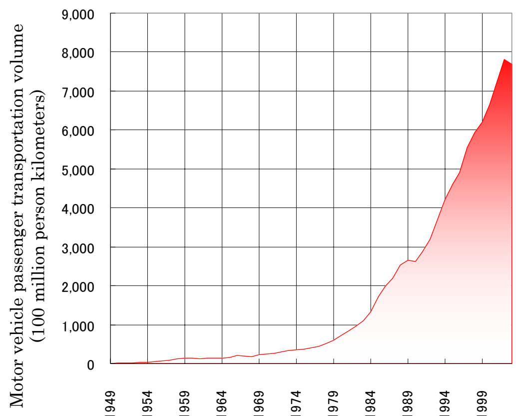


Figure 2-10 Changes in Motor Vehicle Passenger Transportation Volume

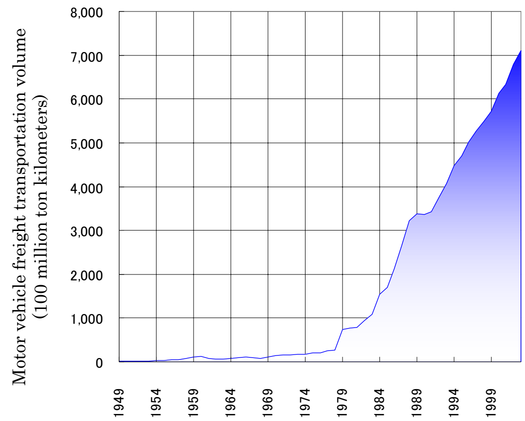


Figure 2-11 Changes in Motor Vehicle Freight Transportation Volume

Next, let's take a look at data on the number of motor vehicles owned. Figure 2-12 and Figure 2-13 show changes in the number of civilian motor vehicles owned. Civilian motor vehicles refer to vehicles owned by citizens, including those for personal and corporate use. Normally, the numeric value of civilian motor vehicles is used when calculating the number of vehicles owned.

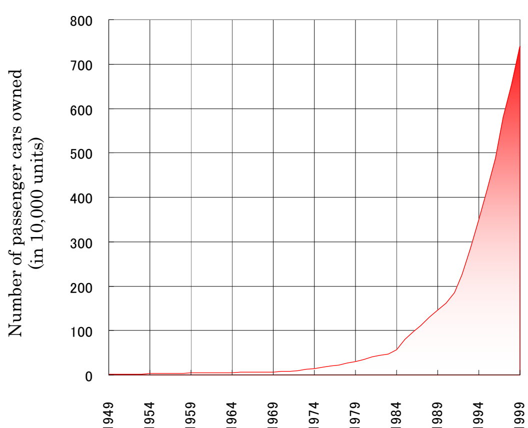


Figure 2-12 Changes in the Number of Passenger Cars Owned

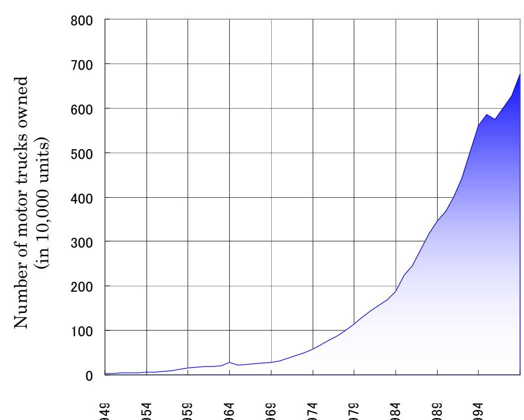


Figure 2-13 Changes in the Number of Motor Trucks Owned

The number of vehicles owned in 2003 is about 24 million - this is a relatively large number in absolute terms. The number of vehicles owned for every 100 persons in

China is 1.8. This is still small in comparison to developed nations, only one-thirtieth, of Japan's 2000 rate of 58.8 vehicles per 100 persons. Private ownership of vehicles is anticipated to grow rapidly in China. Figure 2-14 shows the relation between this ownership ratio and GDP per capita for China. There is a pronounced difference not only between the national average and large cities in coastal areas, but also amongst the large cities. For instance, the ratio of GDP per capita to car ownership in Shanghai is smaller than the national average due to limitations on the number of motor vehicle registrations and specific policies to restrict vehicle ownership.

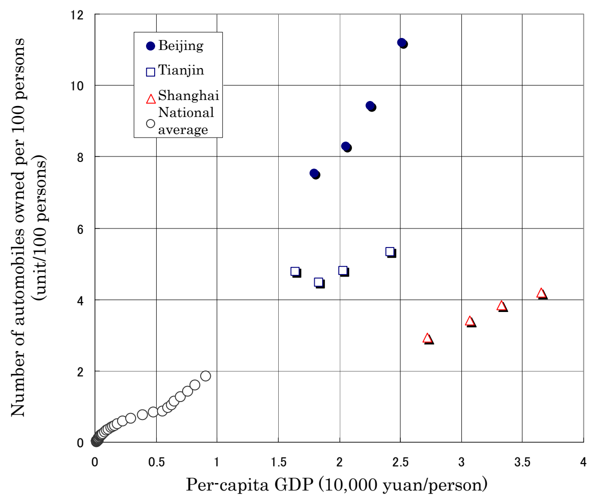


Figure 2-14 Correlations between the Numbers of Automobiles Owned and GDP per capita

Figure 2-15 shows changes in total road length and Figure 2-16 depicts changes in total highway length. Total length of roads reached 1.8 million kilometers in 2003. In particular, the rate of increase has been dramatic for the past several years since 2001. In this year, the government committed itself to making huge investments in road construction. The total length of highways reached 29.7 thousand kilometers and highways make up a mere 2 percent of all roads. But highways length has already surpassed that of Japan. To put this in perspective, one should note that China's land area is 9.6 million square kilometers, 25 times larger than that of Japan. As with increased ownership of motor vehicles, further increases are expected.

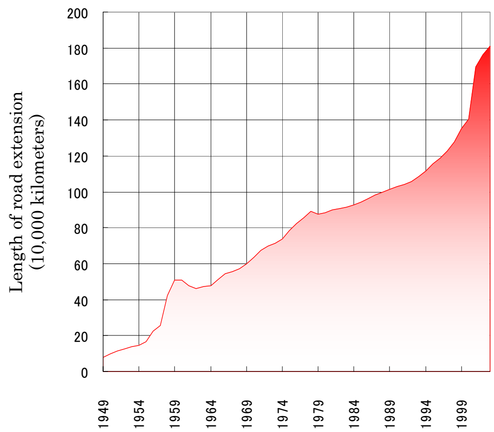


Figure 2-15 Changes in the Length of Roads

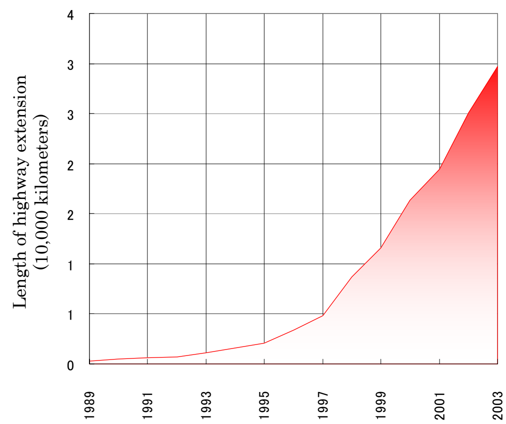


Figure 2-16 Changes in the Length of Highways

2.1.3.3 Vehicle Preference and Use

Prices and fuel efficiency of motor vehicles influence consumers' choices over preferred modes of transportation. As of 2003, approximately 24 million vehicles are owned for civilian use in China. However, the diversity in the types of vehicles has substantially increased in China. Figure 2-17 represents the relation between market price and engine size of 122 new vehicle types available in China in 2003. The figure was drawn up based on real prices of vehicles in China. We can tell from the figure that most types of the vehicles, including imported cars, are being sold at prices below 100,000 yuan. With tariffs on imported cars scheduled to be abolished in 2008, the tendency toward lower-priced cars is expected to further increase in the years to come. Although surveys and other research have indicated a Chinese preference for large-sized automobiles, it is clear that among domestically built cars, those with smaller engines (less than 2000cc) are very popular in the market. This largely has to do with the lower prices and operating costs of smaller vehicles.

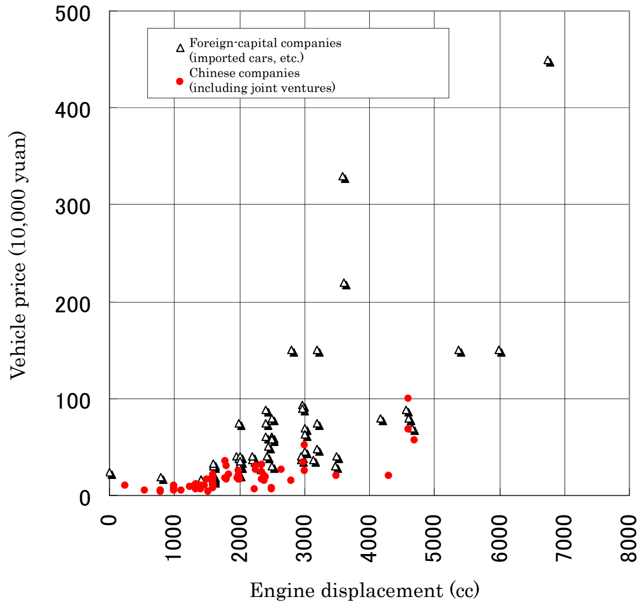


Figure 2-17 Correlations between Vehicle Prices and Engine Displacement in China

Automotive fuels such as gasoline and diesel are subject to price controls in China. Figure 2-18 shows changes in fuel prices in China, indexed to 100 in 1985. Domestic fuel prices are out of synch with international market prices. Fuel prices have been rising even after considering inflation.

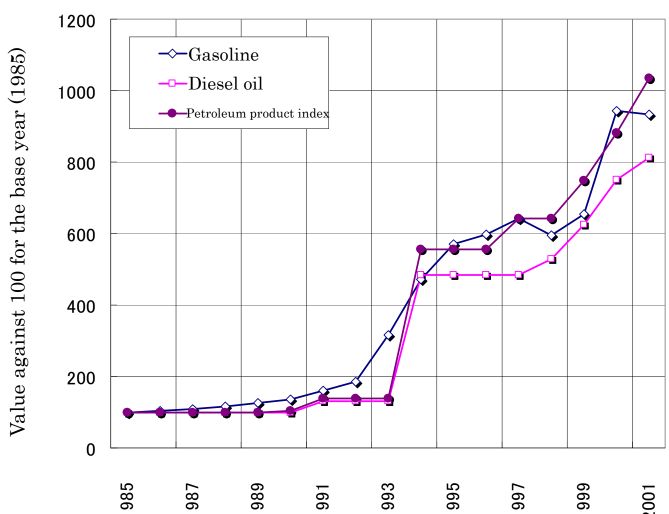


Figure 2-18 China's Domestic Fuel Prices

Statistics of fuel consumption are shown below. Figure 2-19 shows average fuel consumption in relation to transportation volume by passenger and freight transportation companies (retail level usage for fuel consumption is not available). The data on passenger vehicles since 1991 is lacking. Japan's average fuel efficiency is shown for reference in Figure 2-20.

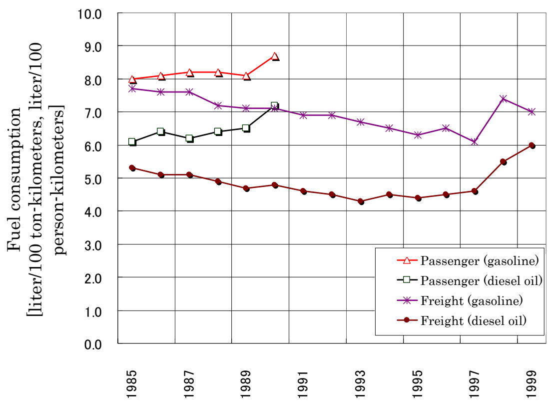


Figure 2-19 Fuel Consumption by Chinese Transportation Companies

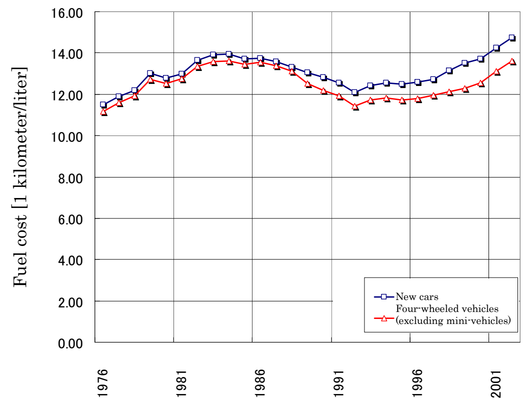


Figure 2-20 Changes in Japan's Average Fuel Consumption

The efficiency of fuel consumption in China, especially with regards to freight transport, appears to have been on a slight decreasing trend throughout the 15 years that statistics are available. However, it is difficult to determine if the trend is consistent or not. The same can be said for Japan's fuel consumption per transportation volume. Figure 2-20 does not simply mean in technical terms, improvement in fuel consumption. For instance, during the bubble economy period from the second half of the 1980s to the early 1990s, large-size passenger cars sold well, as symbolized by the so-called "Cima (Nissan's luxury car) phenomenon," resulting in a decrease in average fuel efficiency during this period. It can be said that the fuel efficiency began to follow a rising curve in line with the rise of compact cars. However, at this stage, it is difficult to confirm any drastic cuts in fuel costs or improvements in fuel consumption from these statistics.

Source

[1] China Statistical Yearbook, Year Book of China Transportation & Communications - Figures 1-8,10,11,15, and 16

[2] Year Book of China Transportation & Communications - Figures 9,12,13, and 19

[3] China Statistical Yearbook, Year Book of China Transportation & Communications -

Figure 14

* For those other than Beijing, Tianjing and Shanghai, year-end populations were used (in accordance with the Statistical Yearbook)

* Data for Beijing, Tianjing and Shanghai are those for 2000~2003.

[4] Gasoline and diesel oil prices are from Price Yearbook of China - Figures 17 and 18

[5] EDMC2003 - Figure 20

EDMC Handbook of Energy & Economic Statistics in Japan 2003 (The Energy Data and Modeling Center, The Institute of Energy Economics, Japan)

2.2 China's motorization at take-off stage

There is no one clear definition of motorization. Most research points to the importance of examining inflection points and thresholds for each country linked to growth in income and other economic development factors. Clearly, motorization is not uniform across and within countries, but the speed and extent of development and demand for motorized vehicles shows some consistency in the past patterns of developed nations. For the purposes of this report, motorization is defined as a process whereby vehicle ownership steadily increases at a speed far exceeding the past rate, reaching the point where 60% of a nation's citizens own automobiles - so that automobiles may be regarded as the primary mode of transportation. We can get a rough idea of when motorization is beginning to accelerate in China, drawing on the past experiences of Japan and Korea. These countries are similar with China, to some extent, in terms of patterns of economic development and share some cultural and institutional features as well. Motorization is at the take-off stage when:

- The rate of increase in car ownership is more than 10 percent annually;
- The ownership rate for automobiles is 1.5 to 2 per 100 persons; and
- Prices of new low-end vehicles roughly equal the annual income of a household.

Table 2.2 Start of Motorization (Japan and South Korea)

	Japan				South Korea		
	Number of passenger cars owned	Per 100 persons	Per-capita GDP		Number of passenger cars owned	Per 100 persons	Per-capita GDP
1963	1.32 million	1.4	576 dollars	1984	0.47 million	1.2	1,853 dollars
64	1.98 million	2.0	630 dollars	85	0.56 million	1.4	1,976 dollars
65	2.3 million	2.3	721 dollars	86	0.66 million	1.6	2,246 dollars
66	3 million	3.0	820 dollars	87	0.84 million	2.0	2,768 dollars
67	4.02 million	3.9	959 dollars	88	1.12 million	2.8	

(Source: Sekai-no Toukei (Japanese Language Publication)

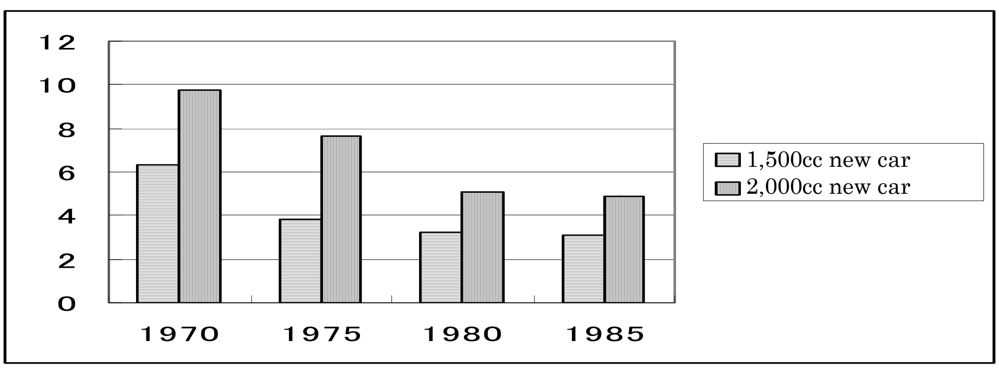
As Table 2.2 above shows, the pattern of motorization take-off period is different even between Japan and South Korea, the two countries with relatively small land areas and less regional disparities (their development was at different time periods and under different conditions). Therefore, it is unlikely that China, a country with vast land area and large population, will clear all of the three yardsticks mentioned above or follow similar paths However, there is some utility in applying these thresholds of acceleration in Japan and Korea to China's case. If you apply these thresholds to China, China is likely to go beyond the two (namely the ownership rate and its annual rate of growth) of the three thresholds in 2004 to 2005 (2005 figures are estimates based on past trends).

Table 2-3 China's Motorization

	Number of passenger cars	(Number of other motor vehicles)	Number of passenger cars per 100 persons	Growth rate	Per-capita GDP
2000	8.53 million	7.16 million	0.7	100	846 dollars
2001	9.94 million	7.65 million	0.8	116	927 dollars
2002	12.04 million	8.5 million	0.9	141	955 dollars
2005	19.78 million	-	1.6	230	1,140 dollars

(Source: Sekai Kokusei Zue (Japanese Language Publication))

Figure 2-21 Changes in Price of New Cars /Household Monthly Income in Japan



Source: Transport White Paper 1993 (Japanese Language Publication)

When you look at the experience of Japan, the prices of cars dropped far below the average household income in the 1970s, when motorization took great strides (See Figure 2-21). In China, prices of low-end new cars are estimated at 29.8 thousand Yuan for the 800cc class and 43.2 thousand Yuan for the 1300cc class (Li Zhidong, Kokichi Ito, and Ryoichi Komiyama 2005. *Outlook for Energy Supply and Demand in China for*

2030 and Consideration of a Northeast Asian Energy Community - The automobile strategy and nuclear power strategy of the ever-present China. (The Institute of Energy Economics, Japan)). Assuming that China's per-capita GDP is 1,000 dollars, the exchange rate is 8.277 yuan to the dollar, and the average number of household members is 3~4, then it can be said that new car prices in China are nearing annual household income. These results suggest that China may have already reached the take-off stage of motorization. In particular, motorization has been rapidly accelerating in high-income coastal regions for the past several years.

3. Future Projections of CO_2 Emissions from Road Transportation in China

3.1 Forecasting method

The ability to forecast future CO_2 emissions from road transportation in China requires an understanding of past and present trends. We set up a three-tiered model that uses logit model analyses to forecast future CO_2 emissions from road transportation in China to 2030 (model results are in the next section). The full model was developed for Japan as well in order to allow for comparisons with China. Only the results for China are discussed in this report. Passenger and freight transportation were modeled separately. The three tiers include an examination of past trends in total transportation volume, road transportation volume, and CO_2 emissions and the model forecasts these major variables into the future. The model is sequentially linked with total transportation and road transportation volume being used as inputs into estimation of fuel consumption and resulting emissions of carbon dioxide (Figure 3-1).

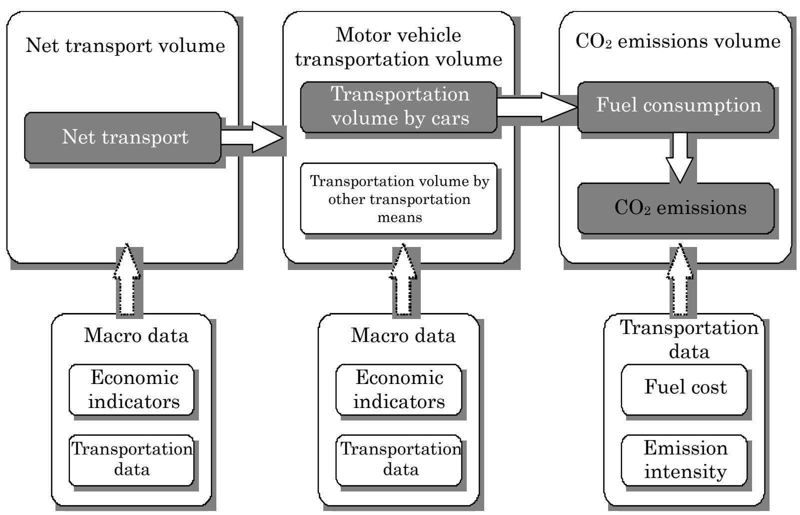


Figure 3-1 Study Flowchart

First we determine total transportation volume (surface transportation), using a regression model with mainly macroeconomic variables. In past studies, national income and total length of railway tracks were used for passenger traffic and gross domestic production and industrial and agricultural production for freight traffic. In this model, real GDP and road length are used as variables for both passenger and freight traffic. Equations were developed using past data on these variables and total transportation volume as a function of these variables. The coefficients from these equations were used in forecasting future emissions.

Second, we develop models to explain and estimate road transportation volume. To achieve this objective, we adopted a logit model. We set the probability of choosing automobiles among each mode of transportation as P, assuming that this value represents the utility of choosing automobiles and then estimated the value using least squares regression. In most traditional models, one represents utility as the maximization of objectives such as convenience, economy, or other consumer preference parameters. In this model, macroeconomic data such as the average price of automobiles (a figure determined through weighing aggregate value of imported cars with changes in machinery shipment prices), disposable income per capita, and a fuel price index were used to explain mode choice for both passenger and freight transportation.

Finally, we calculated fuel consumption attributed to road transportation volume and estimated CO_2 emissions, using a conversion factor of CO_2 emissions per unit of fuel consumption. To convert transportation volume into fuel consumption, the model uses historical data for Chinese Public Roads and Transportation Enterprises. This procedure may result in a conservative (lower) estimate of fuel consumption from road transportation for China, given that actual fuel efficiency values are probably lower in China for private users. Fuel consumption data is notably lacking for China and data for transportation companies is more easily available.

3.2 Results

The forecast for fuel consumption contributed by road transportation from the model is shown in Table 3-1. Since it was statistically difficult to separate diesel and gasoline consumption, it is assumed here that all transportation is fueled by gasoline. It is also based on a future economic growth scenario in which the base case is 7% annual growth and the slow growth case is 6% annually, following the EDMC study. Two additional scenarios were also used for forecasting energy consumption including i). holding fuel prices at current levels and ii). a doubling of fuel prices from current levels.

Table 3-1 Forecast of Energy Consumption by Vehicles in China

	Standard growth case [1 million toe]		Low growth case [1 million toe]	
	Gasoline price constant	Gasoline price double	Gasoline price constant	Gasoline price double
2000	75			
2010	115	94	113	92
2030	187	153	182	150

The fuel consumption data is converted into CO_2 emissions shown in Table 3-2.

Table 3-2 Forecast of CO_2 Emissions by Vehicles in China

	Standard growth case [1 million t-CO_2]		Low growth case [1 million t-CO_2]	
	Gasoline price constant	Gasoline price double	Gasoline price constant	Gasoline price double
2000	225			
2010	344	280	340	276
2030	558	458	545	448

The three-tiered model does not address regional differences and account for the impacts of urbanization. The outcome of the model shows that 86 million tons of oil equivalent (toe) from gasoline and diesel consumption in 2003 will increase to 110 million toe in 2025. A forecast by China's National Development and Reform Board predicted that current fuel consumption of 70 million toe will rise to 130 million toe around the same time period. These estimates are quite close.

4. Verification of Model Estimates (Comparison with Energy Consumption Statistics)

In line with its economic growth, China's energy consumption has increased sharply and its CO_2 emissions have also risen. Although China's GDP per energy unit (KTOE) has been increasing, it stood at almost the same level as India's GDP and far below Japan's GDP in 2000 (Table 4-1). China became a net importer of crude oil in 1993 and its imports in 2000 came to about 70 million tons.

Table 4-1 Changes in China's Total Energy Consumption and CO_2 Emissions (1990-2000)

	1990	2000
China		
Energy consumption (1 million toe)	880	1,140
CO_2 emissions (1 million tCO_2)	2,256	2,982
GDP (billion 1995 US$ exch. rate)	398	1,041
GDP per energy unit ($/K toe)	0.45	0.91
India		
Energy consumption (1 million toe)	365	517
CO_2 emissions (1 million tCO_2)	595	974
GDP (billion 1995 US$ exch. rate)	276	470
GDP per energy unit ($/K toe)	0.76	0.91
Japan		
Energy consumption (1 million toe)	446	521
CO_2 emissions (1 million tCO_2)	1,015	1,178
GDP (billion 1995 US$ exch. rate)	4,925	5,684
GDP per energy unit ($/K toe)	11.04	10.91

Source: IEA

Table 4-2 Changes in China's Crude Oil Imports and Production (1990-2000) (in 10,000 tons)

	1990	2000
Imports	-2,921(Exports)	7,027
Production	13,810	16,300

(Source: Sekai Kokusei Zue (Japanese Language Publication))

IEA CO_2 emissions data are compiled from energy consumption for each sector in each country. According to these statistics, the share of transportation sector at large is significantly low for China as shown in Table 4-3.

Table 4-3 Changes in Sector-by-Sector CO_2 Emissions in China (Unit: CO_2 million tons)

	1990		2000	
	Total amount	Share	Total amount	Share
Electric power energy	690	31%	1,690	52%
Manufacturing	960	42%	940	29%
Transportation	120	5%	240	7%
(Road transportation)	(61)	(2.7%)	(150)	(5%)
Households, etc.	490	22%	400	12%
Total	2,260		3,270	

Source: IEA

There are no official statistics available on CO_2 emissions from road transportation in China. This was confirmed through interviews to the National Environmental Protection Bureau and National Statistic Bureau by The Institute for Economic Research at Kyoto University and Japan International Transport Institute in 2005. In addition, it must be pointed out that China's energy consumption statistics are unreliable for transportation as half of consumption in transportation sector is counted in other categories （*A Guide to China's Energy Statistics* (Sinton and Fridley, 2001) & *Energy in China: Transportation, Electric Power and Fuel Markets*, 2004 (Asia Pacific Energy Research Centre - APERC)).

The share of transportation sector in developing countries is usually lower than that of developed countries. In China's case, as pointed out in the report by APERC (2004), energy consumption data in the transportation sector is limited to that of large transportation service providers. For these reasons, official figures are suspect and deviate from reality. According to the study by the same institute and others, the share of the transportation sector reaches 12 to 13 % instead of the official figure of 7%. In this report and our model, CO_2 emissions in road transportation are calculated based on the energy consumption deduced from the traffic volume. The CO_2 emissions from road transportation in China are estimated at 225 million CO_2 tons as shown in Table 3-2.

According to the figures for energy consumption by the transportation prepared by the APERC (Table 4-4), the increase in road transportation is remarkable. Table 4-5 shows the changes in surface traffic volume by sector, using the data from APERC 2004 (conversion factors were used to arrive at standardized units - see p. 32). Using the data from Tables 4-4 and 4-5, the calculated fuel efficiency of road transportation noticeably deteriorated between 1990 and 2000, as ton-kilometer per ktoe dropped from 1,420 to 1,038.

Table 4-4 Changes in Energy Consumption by Mode of Transportation (1990-2000)

(Unit: 1 million TOE)

	1990		2000		Growth rate
	Consumption	Share	Consumption	Share	
Railway	14.9	28%	13.0	14%	87
Road	25.5	48%	65.5	68%	257
Marine transportation	11.4	21%	12.0	13%	105
Aircraft etc.	1.8	3%	5.7	6%	317
Total	53.5		96.2		180

Source: "Energy in China: Transportation, Electric Power and Fuel Markets" Asia Pacific Energy Research Centre

Table 4-5 Changes in Total Transportation Volume by Land Transportation (1990-2000)

(Unit; 100 million ton-kilometers)

	1990 (share)	1995 (share)	2000 (share)	2000/1990
Railway	1,323(79%)	1,641(76%)	1,810(73%)	137
Road	362(%)	516(24%)	680(27%)	188
Total	1,685	2,157	2,490	148

Source: "Energy in China: Transportation, Electric Power and Fuel Markets" Asia Pacific Energy Research Centre

5 The Future of Indian Road Transport and CO_2 Emissions

India has undergone significant changes in its economy and society in recent decades. With significant liberalization and investment, India has shown growth potentials that present both challenges and opportunities. One of the major challenges concerns the Indian road transport sector. In order to accommodate growth in a sustainable manner, this sector requires considerable investment for expansion, upgrading, and maintenance and planning for reduction of negative externalities such as road safety and global environmental pollution. Motor vehicle growth is unique in India, but shares some similarities with growth patterns in other nations. Comparisons with China reveal critical differences in timing and potential future trends in road transport and emissions. Reducing excessive fuel and energy consumption from transport is critical for India's development. The future growth patterns in travel as well as emissions for India are expected to accelerate in the longer-term horizon. By 2050, India should have overtaken China in numerous parameters of growth and emissions.

5.1 *Travel and Vehicle Patterns in India*

Vehicle utilization, load factors, and trip distances are different in India than in developed countries (mainly due to road conditions). Nevertheless, these parameters are changing with increased utilization, longer trip distances, and lower load factors than in the past. Mode competition and substitution are prominent among non-motorized modes, public transport, and two-wheelers. Public transport vehicles share of all modes and levels serviced by this mode are declining, but this mode of travel continues to meet travel demand for the majority of the population.

Ownership of vehicles must be differentiated from use of vehicles. Households who own vehicles (such as two-wheelers) do not necessarily use these vehicles for all their trips. Vehicles are status symbols, but their daily use is unaffordable to a majority of the population. The relatively skewed distribution of income keeps income elasticity values for ownership and use at low levels. Nearly 32 percent of registered motor-vehicles in India are located in 23 metropolitan cities and 90 percent of these vehicles are for passenger travel.

Although there are more gasoline-based vehicles than diesel-fuel vehicles, diesel consumption is greater than petroleum consumption. There has been a significant shift from rail to road for freight transportation in India, especially in the 1980s, that explains this pattern of fuel consumption. Road transport accounts for 62 percent of

India-wide diesel consumption (with trucks at 35 percent of overall diesel consumption). Ninety-eight percent of gasoline consumption in India is used by the road transport sector (with two-wheelers accounting for 51 percent, cars/taxis for 32 percent, and three-wheelers for 13 percent). The price differential between diesel and petrol also explains higher diesel consumption levels.

The current modal split in India limits the amount of greenhouse gas emissions because of the lower fuel consumption by two-wheelers compared to passenger cars. Even the high volume and activity by these smaller personalized vehicles is still relatively favorable from an emissions perspective. In contrast, local emissions from two-wheelers are relatively higher.

Differences in consumption of land, energy (fuel) consumption, road safety, and emissions between motorized modes are significant. Public transport uses the least amount of energy, consumes the least amount of road space in terms of the same level of activity, and is the most environmentally friendly mode. Two-wheelers fall second in all these attributes except road space (two-wheelers occupy the most space standardized by activity). Cars are the least efficient in terms of energy and fuel consumption (second in terms of road space consumption) and the highest emitting mode.

Indian consumers are extremely sensitive to price and increased mode substitution from two-wheelers to four-wheelers would occur only with reduction in existing price levels of passenger cars. It is estimated that seventy percent of the operating costs are for fuel. Adding taxes and tariffs, these costs limit vehicle ownership for a large majority of Indians. The existing modal split will not change (roughly 75 percent for two-wheelers and 25 percent for other vehicles) in the foreseeable future.

Road conditions also determine mode choice and modal structure. Road development and building require high levels of investment and many have pointed to lack of road capacity as one of the major constraints to growth. Infrastructure investment (including transportation) needs are estimated to be $150 billion for the next five years.

Table 5-1 Total Road Length (2001)

	Total road length	Pavement ratio	Extension per 1,000 persons	Extension per 1km^2
China	1.7 million kilometers	22.4 %	1.33	0.18
Japan	1.17 million kilometers	77 %	9.20	3.14
India	3.22 million kilometers	45.7 %	3.36	1.01

Source: Sekai Kokusei Zue (Japanese Language Publication)

The potential for diffusion of motorized two-wheelers in smaller urban areas and rural areas is large. The extreme urban concentration is likely to remain the case for passenger cars. In the longer-term, reasonably priced and fuel-efficient cars will lead to widespread and faster diffusion of these vehicles.

Assumptions about the growth of the middle-class and their consumption patterns are intimately related to projected dramatic growth in passenger cars. Estimates of India's middle-class range from 50 to 200 million. However, most of this middle-class still is unable to afford and switch to use of passenger cars. Passenger cars have become more affordable only recently to a larger (albeit still limited) number of middle-class Indians. The last five years has seen the expansion of marketing, financing, and credit mechanisms targeted at the middle-class purchases of motor vehicles.

Table 5-2 Number of Motor Vehicles Owned

	1990 (per 1,000 persons)	2002 (per 1,000 persons)
China	550(4.7)	2,050(16)
Japan	5,770(466)	7,400(582)
South Korea	340(79)	1,400(297)
India	400(4.7)	1,190(12)

Source: Sekai Kokusei Zue (Japanese Language Publication) (Unit: 10,000)

Export and sourcing potentials of automobile and component parts industry sectors will influence the production of affordable automobiles. But the Indian automobile industry is not globally competitive at this time and is not expected to be a major global player in the near future. Scale and scope economies will assist in continued profitability and growth of an automobile industry in India. In the longer-term, competition in the industry is healthy and will lead to mass production and higher sales of low-priced vehicles. This includes a more profitable environment for automobile producers.

Rural incomes are much lower than urban incomes, but disposable income is higher in rural areas because of lower costs of living compared to urban populations. This target market will be critical for considerable growth in vehicles, especially two-wheeler vehicles. Domestic firms will spearhead the growth in automobiles and other motor vehicles with their strong knowledge of Indian markets on the production and consumption sides. The maturing of the industry and transition to passenger cars will accelerate by mid-century.

5.2 *Comparisons with China*

Some convergence is occurring and expected, but India still remains quite different than China in terms of economic structure, political organization, and growth patterns. Both nations have dramatic differences between urban and rural populations and growth is concentrated in certain regions and in urban areas. Income inequality has increased significantly in China (especially in rural areas) and has reached the same level as India.

Rural industrialization is absent in India. China has used rural industrialization as one of the cornerstones of its development policies. However, production is dominated by state-owned enterprises and consumer markets remain small and immature. Some have suggested that rural industrialization is equated with urbanization in China - this may explain the high rates of urbanization.

China has built a strong manufacturing base and modernized agriculture much earlier than India. In China, large surpluses from the agriculture sector were used for development with heavy state intervention, even in the more recent periods of economic growth. India has concentrated on building a highly-skilled labor force with a heavy concentration in the service sector. India has privatized more of its industries than China and governance is much more decentralized than in China.

Problems with Chinese energy statistics are suspected. Statistics that show India with higher energy consumption and contribution of CO_2 emissions from the road transport sector than China. Specific problems with Chinese transportation and energy statistics are present.

In both countries, industry and electricity dominate as major end-users in energy consumption and contributors to emissions. Coal is the dominant fuel used in both nations. The contribution of transportation to greenhouse gas emissions is still limited and primarily derives from urban metropolitan areas in these two nations. Transportation will be the fastest growing sector of emissions and energy consumption in the future.

Surprisingly, India has a greater potential for growth in consumer markets over the longer-term than China. Indian corporations seem to have a higher technological capacity and integration with worldwide automobile producers. India is more integrated with world markets (both from the consumption and production sides) as foreign firms want to use India as a base for lower-wage labor for production and development of markets for future production. Chinese firms, who remain quasi-governmental, are not easily transformed and consumer markets in China are quite differentiated from Western markets. India's strategy is not to produce for export markets, but to serve producers and build indigenous production capability through collaborations with and suppliers to foreign companies.

5.3 *Travel and Emissions Forecasts*

A range of estimates for future travel demand by the road transport and carbon dioxide emissions exist. There has been a considerable mode shift from railway to road transport in India in the last five decades. The railway share has shifted from 88 percent to 40 percent for freight transportation and 68 percent to 20 percent for passenger transport

Table 5-3 Railway Service Kilometer

	Service kilometer	Per 10,000 persons	Per 100 km^2
China	59,000 kilometers	0.46	0.6
Japan	20,000 kilometers	1.6	5.3
India	63,000 kilometers	0.6	1.9

Source: Sekai Kokusei Zue (Japanese Language Publication), Sekai-no Toukei (Japanese Language Publication)

Table 5-4 Railway Transportation Volume

	Passengers (100 million person-kilometers)		Freight (100 ton-kilometers)	
	1990	2001	1990	2001
China	2,613	4,767	10,622	14,575
Japan	3,875	3,854	272	222
India	2,956	4,570(2000)	2,358	3,124(2000)

Source: Sekai Kokusei Zue (Japanese Language Publication)

The share of road transport of total travel has risen to 60 percent (from 12 percent) in freight and 80 percent (from 32 percent) for passenger transport. Currently, the Planning Commission estimates 800 billion ton-kilometers and 2300 billion passenger-kilometers are serviced by the transport sector (air, rail, and road). Estimates vary considerably. In fact, another estimates the same levels (800 and 2300 for freight and passenger) serviced by road transport.

A Planning Commission estimate forecasts a rise of 5 times for freight and 4 times for passenger road transport for total activity from 2000 to 2020. Another estimate (at the high end) from a research organization suggests a slower rise for freight and passenger up to 2030 with a higher rise in passenger activity (5 times) than freight activity (4 times). Researchers at The Energy and Resources Institute (TERI) estimate demand for transport services will increase from 6-12 times (depending on growth scenarios) for freight and only 3 times for passenger transport to the year 2025. Public investment in infrastructure has declined from 23 percent of Plan funds in the early 1960s to only 12 percent in the 1980s and 1990s.

The International Energy Agency (IEA) projects that transport is second to electricity in the fastest growing sector of energy consumption in India. IEA estimates that the transport sector will contribute 201 million tones (Mt) of CO_2 emissions in 2030 (a 113 percent growth rate from 2002) - its share of total consumption rises from 22 percent in 2002 to 25 percent in 2030.

Projecting from past IEA data on fuel combustion of carbon dioxide emissions from road transport in India, it is anticipated that about 150 Mt of CO_2 will be from road transport (around 75 percent of the IEA model estimate for 2030). This represents an increase of 1.7 times from 2000 levels for road transport.

An application of an integrated assessment model for India estimates that the carbon dioxide emissions from the entire road transport sector will increase almost 4 times from 2000 to 2030. According to this model, the Indian transport sector (for all modes) would contribute up to 500 Mt of CO_2.

5.4 Future of India's Road Transport Sector (Outlook in comparison with China)

The largest constraints in the future growth of the Indian road transport sector, fuel consumption, and global environmental emissions are affordability and lack of infrastructure. Combined with a skewed income distribution in India, vehicle ownership and use is unlikely to grow exponentially, even in the medium and long-term horizons. Both urbanization and passenger cars are concentrated at this time and will remain so in the distant future. Modal shifts and competition between modes need to be closely examined for prediction of future road transport and emissions profiles.

A distinction must be made between ownership and use of motor vehicles. Income and price elasticities of use are lower than those of ownership. However, growth in fuel consumption is expected to increase dependency on oil. China has stronger short and medium-term potential for motorization and global environmental emissions, but India may see higher longer-term growth in vehicles, fuel consumption, and emissions than China. By 2050, India should be comparable or ahead of China.

6. Future Research Directions

In the Kyoto Protocol, Japan has committed to reduce its CO_2 emissions by 6 percent from the level in the base year (1990 in principle) to 1,163 million t-CO_2 in the target years of 2008 to 2012. Since Japan's CO_2 emissions in 2002 came to 1,331 million t-CO_2, the country has to reduce its annual emissions by 168 million t-CO_2 by the target years. Japan set a guideline to reduce 11 million t-CO_2 from the 2002 level of 261 million t-CO_2 in the transportation sector.

Table 6-1 Japanese Government's Kyoto Protocol Goal Attainment Plan (2005)

Unit; 1million t-CO_2	Total	Transportation sector
Base year (FY1990)	1,237	217
Actual results in FY2002	1,331	261
FY2010 current measure case	1,311	259
FY2010 reduction commitment	1,163(-6%)	
(FY2010 target for the transportation sector)		250)

Source: Japanese Government

Assuming all CO2 emissions in transportation sectors stem from use of oil as a energy source, using the share of road transportation to CO_2 emissions in 2002, and using the growth rates since 1990 as set forth in IEA statistics, we calculated CO_2 emissions from road transportation and projected increases from 1990 based on the figures in Table 6-1. As the target for transportation sectors in 2010 is close to the 2002 figure, we inferred CO_2 emissions from road transportation in 2010, using the share of road transportation in 2002 from IEA statistics (see Table 6-2.)

Table 6-2 CO_2 Emissions from Road Transportation Sector in Japan

Unit: 1million t-CO_2	FY2002	FY2010
Emissions from the road transportation sector (Share of the road transportation sector)	235(17.7%)	225(19.3%)
Increase from FY1990	43	33

Source: Japanese Government, IEA

With regard to reduction of CO_2 emissions – annual reduction of 11 million t-CO_2 by the transportation sector and 10 million t-CO_2 by the road transportation sector – as part of achieving the target Japan has committed in the Kyoto Protocol, the Japanese government has set forth the following measures in its Kyoto Protocol Goal Attainment Plan (2005). The move represents the Japanese government's efforts to reduce ever-increasing CO_2 emissions from the road transportation sector by employing various measures.

○ Promotion of the use of public transportation (e.g., establishment and enhancement of the convenience of public transportation facilities, commuter traffic management, etc.)
○ Promotion of eco-friendly use of motor vehicles (e.g., promotion of idling stop, eco-driving, etc.)
○ Construction of a system for smooth road traffic (e.g., adjustment of vehicle traffic demand, promotion of intelligent road transportation system (ITS), etc.)
○ Realization of environmentally sustainable transport (EST) (e.g., pioneering efforts on regional basis)
○ Promotion of CO_2-reduction efforts through collaboration between shippers and forwarders (e.g., revision of the energy-saving law, Green Logistics Partnership conference, etc.)
○ Promotion of efficiency of physical distribution (e.g., modal shift, promotion of efficient trucking, etc.)
○ Equipment-unit measures in the transportation sector (e.g. expansion and diffusion of leading-running standard-complying vehicles, diffusion of energy-efficient cars/clean-energy cars, restraints on traveling speed of large trucks, etc.)

Meanwhile, 15 EU countries have committed to reduce their greenhouse-gas emissions by target years (between 2008 and 2012) by 8 percent from the level in the base year (1990). CO_2 emissions from the road transportation sector in the 15 EU countries have been calculated as follows by using European Environment Agency's documents and IEA statistics.

Table 6-3 CO_2 Emissions from Road Transportation Sector of EU 15

Unit: 1 million t-CO_2	2002	2010
Emissions from the road transportation sector (Share of the road transportation sector)	816 (19.8%)	816 (20.9%)
Increase from FY1990	152	

Source: European Commission, European Environment Agency, IEA

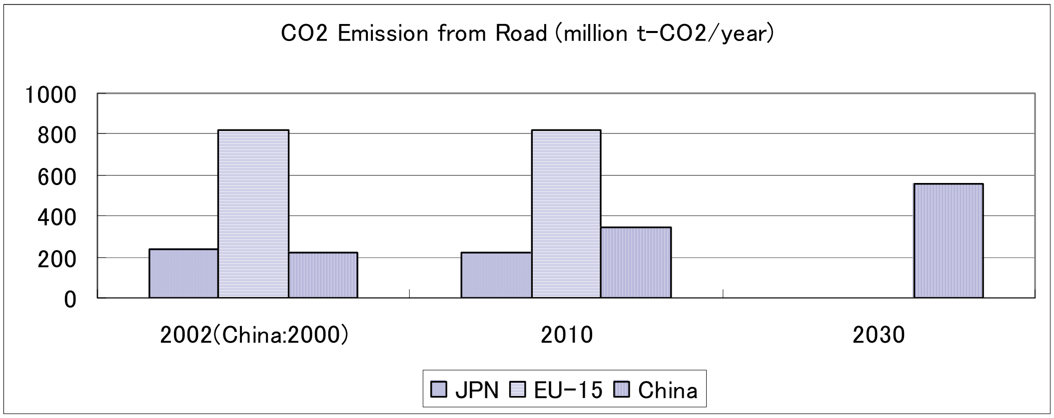
Incidentally, the figure for 2010 in Table 6-3 is the one based on the assumption that various measures have been implemented. If the situation went along with the status quo with regard to emissions from the road transportation sector, it would increase the level of emissions by the sector by 83 million t-CO_2 from the level in 2002 to 899 million t-CO_2 in 2010, increasing the share of the sector to 23 percent as compared with the case where the 15 EU countries as a whole attained their reduction commitment in the Kyoto Protocol (calculated from figures in the European Commission and IEA).

The EU-15's figure for 2010 can be achieved only when Kyoto mechanisms and other measures have been implemented, in addition to the measures currently being implemented. In this connection, Europe began the implementation of emissions trading, one method of the Kyoto mechanisms, in 2005. But it should be noted that Europe has only recently begun studying how to incorporate the transportation sector, including the road transportation sector, into the emissions trading system or whether or not other methods should be employed. This suggests that Europe has to make a good deal of effort to attain these goals, as in the case of Japan.

Apparently, it is still difficult to reduce CO_2 emissions from road transportation if we rely only on reductions from developed nations following the Kyoto Protocol. Taking a look at Japan and EU-15 countries, even if they are successful in curbing the growth of CO_2 emission with various additional measures by 2010, if the rapid economic development and motorization in developing countries causes huge increases in CO_2 emissions from road transportation, effective measures not only in developed countries but also in developing countries will have to be taken for the global environment.

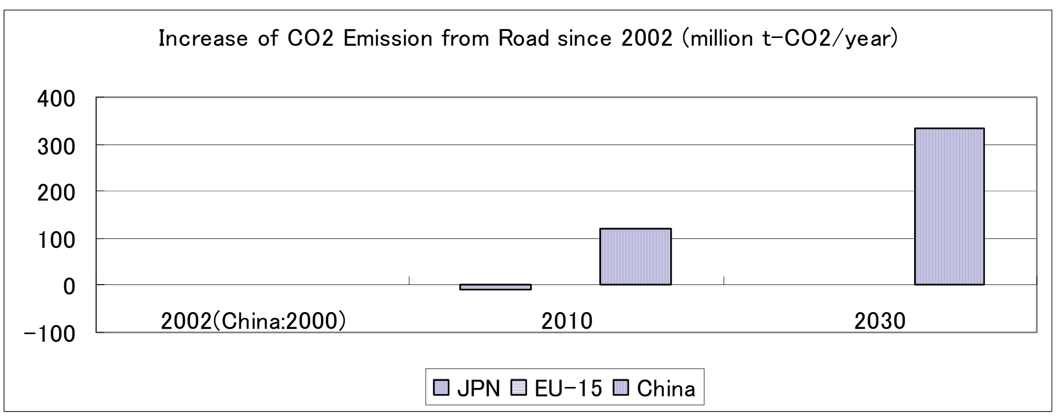
In order to understand the impact of road transportation sector's CO_2 emission in developing countries, the actual results (2000) and forecasts (2010 and 2030) of CO_2 emissions from China's road transportation sector, and the actual results (2002) and forecasts (2010) of CO_2 emissions by the transportation sectors in Japan and EU-15 are compared in Figures 6-1 and 6-2.

Figure 6-1 CO_2 Emissions from Road Transportation Sectors in Japan, Europe and China



Source: Table 3-2, Table 6-2, Table 6-3

Figure 6-2 Increase of CO_2 Emission from Road Transportation Sectors in Japan, Europe and China



Source: Table 3-2, Table 6-2, Table 6-3

Even if CO_2 emissions from the road transportation sectors of Japan and EU15 in 2010 are kept at the level in 2002, emissions from China (344 million t-CO_2) in 2010 will exceed those from Japan (225 million t-CO_2) in the same year. The increase in CO_2 emissions from China's road transportation sector from 2000 to 2010 comes to 119 million t-CO_2, about 10 times of the amount of the decrease of 12 million t-CO_2 in emissions from Japan from 2002 to 2010, bringing Japan's emission reduction efforts to naught.

Moreover, CO_2 emissions from China's road transportation sector in 2030 (558 million t-CO_2) is more than double Japan's emissions in 2010 (225 million t-CO_2), and the increase in emissions in China from 2000 to 2030 (333 million t-CO_2) far exceeds Japan's level in 2010 (225 million t-CO_2). From the standpoint of the prevention of global warming, transportation activities of China alone will make the CO_2 emission control measures implemented by Japan and Europe, with huge costs, meaningless.

India is also expected experience the take off of motorization on the heels of China. A crude extrapolation of CO_2 emissions forecast in India for road transportation sees a value of 150 million t-CO_2 in 2030 - while lower than China and Japan, this estimate is extremely conservative based on past levels of volume and fuel consumption. The range of estimates for the entire transportation sectors is estimated at 201 million t-CO2 to 500 million t-CO2 in 2030. It should be noted that India's potential impact is comparable to China's.

As is clear from the above discussion, CO_2 emission control measures should be urgently adopted by China, India and other developing countries in order to prevent global warming. It is also necessary to recognize that such measures are in the interest of developing countries, from the viewpoint of energy security. In China's case for instance, Tables 3-1 and 4-2 suggest that oil consumption by China's road transportation sector in 2000 is about 75 million tons, accounting for about one-third of the total oil consumption in the country. The road transportation sector is one of the most energy-intensive sectors in China, which is now a net oil importing country. If the road transportation sector, whose transportation ton-kilometer per KTOE deteriorated from 1,420 to 1,038 in the last 10 years, reduces oil consumption in an efficient manner, it would contribute to sustainable growth of the country's economy.

Urgent CO_2 emission curbing measures in road transportation in developing countries are good for sustainable development of developing countries from the standpoint of energy consumption. These measures are not contradictory, but rather compatible with and necessary for economic development.

Kyoto University's Institute of Economic Research and Japan International Transport Institute have come to the above perception in the course of their study on motorization in developing countries, mainly China and India. The two institutions intend to further promote research and study in the following directions.

An international framework to address global warming should be built and implemented quickly and in a large scale in response to acceleration of motorization in fast developing countries at the early (but rapidly advancing) stage of motorization in China and India. This should begin immediately and hopefully within the next 10 years.

In view of the fact that the Clean Development Mechanism of the Kyoto Protocol has not been fully utilized especially in the transportation sectors, including the road transportation sector, the development of an international framework to control CO_2 emissions from that sector should focus on the following three points, so that the controls will be implemented immediately and on a large scale.

① Promotion of technology transfer to developing countries

Clarifying the impact of and impediments to dissemination of the technologies to developing countries which are suitable for effective curbing of CO_2 emissions.

② Resolution of problems, such as difficulty in establishing a base line for the CDM of the Kyoto Protocol and monitoring it

Reviewing the current CDM scheme regarding road transportation, extracting technical problems and impediments to the use of CDM, and considering improvements.

③ Utilization of already initiated CO_2 emissions trading market in order to effectively utilize economic principles

Since it is important to utilize market principles in order to effectively implement measures on a global scale, including developing countries, methods for utilizing CO_2 emissions trading market will be studied with regard to measures in the area of road transportation.